Public Roads

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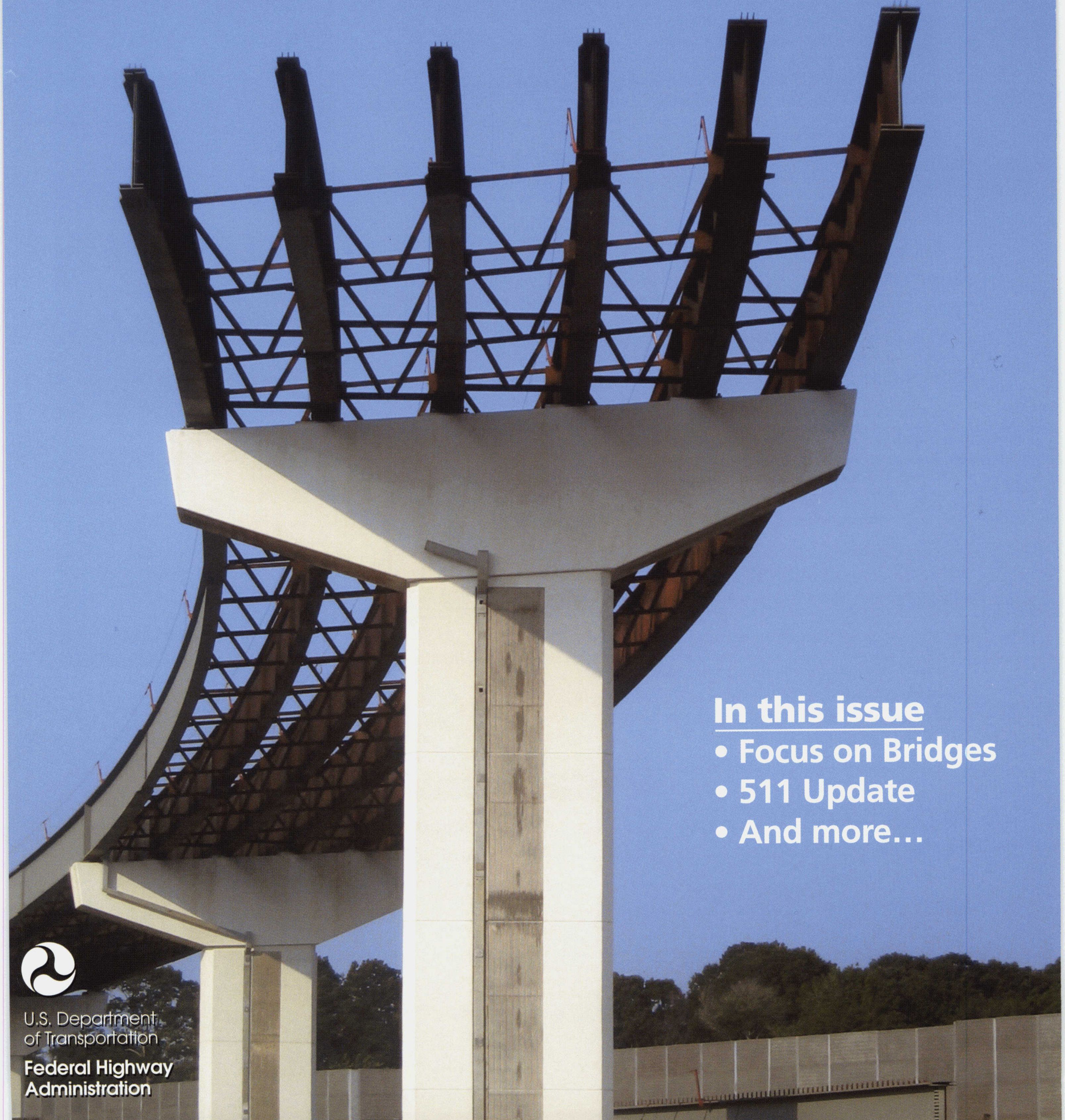
November/December 2003



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U.S. Department of Transportation

Federal Highway Administration

Public Roads

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—featuring developments in Federal highway policies, programs, and research and technology—

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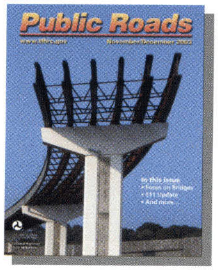

Front cover—A new I-95 bridge taking motorists over northern Virginia's Springfield Interchange near Washington, DC, directly onto I-95S is nearing completion in this photo. The bridge, about 37 meters (120 feet) at the highest point, was constructed from both ends, leaving the middle to be connected during two Saturday night operations. The Springfield Interchange Project is scheduled for completion in late 2007. *Photo: Kevin Connor, FHWA.*

Back cover—This aerial photograph of the new north-south I-95S bridge connecting the inner loop of the Nation's Capital Beltway, I-495, directly to I-95S shows the project's status 1 week prior to the Saturday night operations that closed the two spans. All I-395N lanes and the ramp from I-395N to the inner loop were closed to traffic to provide a safe work zone while crews installed steel beams. The closures began at 6:00 p.m., and by 10:00 a.m. on both Sundays, all lanes were reopened to traffic. *Photo: Tracy Keiger, VDOT Springfield Interchange.*

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Federal Highway Administration

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Guest Editorial

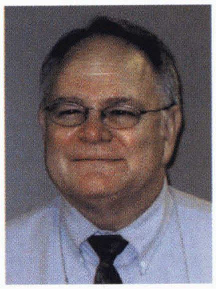
Building the Bridges of the Future

The Federal Highway Administration (FHWA) is a strong partner and leader in working with State and local agencies to ensure that our Nation's aging bridges remain safe and that new bridges are designed and constructed with the future in mind. Accomplishing this objective is challenging when transportation agencies are faced with shrinking budgets, attrition of experienced engineers, and highways and bridges that are stretched to their limits in capacity and lifespan.

The Administration's new transportation reauthorization package proposes to revise the current highway bridge replacement and rehabilitation legislation to provide greater flexibility so that States and local governments can use bridge funds for systematic preventative maintenance. This change will enable agencies to better implement the recommendations in the *bridge management systems.*

The proposed legislation contains a new initiative called the Long-Term Bridge Performance program. This 20-year effort will provide the data and improved tools for helping States and local communities better manage their bridges. The proposed program holds considerable promise for providing a greater understanding of new materials and techniques under actual field conditions. The Innovative Bridge Research and Construction Program that was funded under the Transportation Equity Act for the 21st Century (TEA-21) successfully encouraged the use of high-performance materials and techniques in bridge construction. Through the new reauthorization, the Administration proposes expanding this program to include the development of new structural systems that last longer and that can be built faster.

In addition to changes in legislation, FHWA and the States are working together to look for ways to accelerate the design and construction of projects. Given the numerous technologies available today, we



believe that many construction projects need not take as long as they do. Accelerating these projects to reduce construction time from years to months and even days would improve the transportation experience for the motoring public.

FHWA is committed to working with States and the transportation industry to find innovative and sometimes *audacious* methods of safely accelerating the completion of projects. This acceleration can be accomplished only through a cooperative effort by the entire highway and bridge construction industry. Fostering this cooperation will be one of the FHWA focus areas.

In this issue of PUBLIC ROADS, prefabricated construction, cooperative efforts to restore bridges quickly, and a glimpse of future FHWA research initiatives are highlighted. The articles in this issue bring together many of the ideas that have been discussed over the years and show that construction projects can be built quickly and efficiently, while addressing the concerns of the entire community.

Without a doubt, this is an exciting time to be an engineer! Innovative ideas and technologies are evolving, and FHWA will continue to be a strong partner and leader in innovations that help build and preserve America's bridges and highways for the safety and security of our traveling Nation.

Raymond J. McCormick

Raymond McCormick
Senior Structural Engineer for
Bridge Programs
Federal Highway Administration

Getting Ahead of the Curve

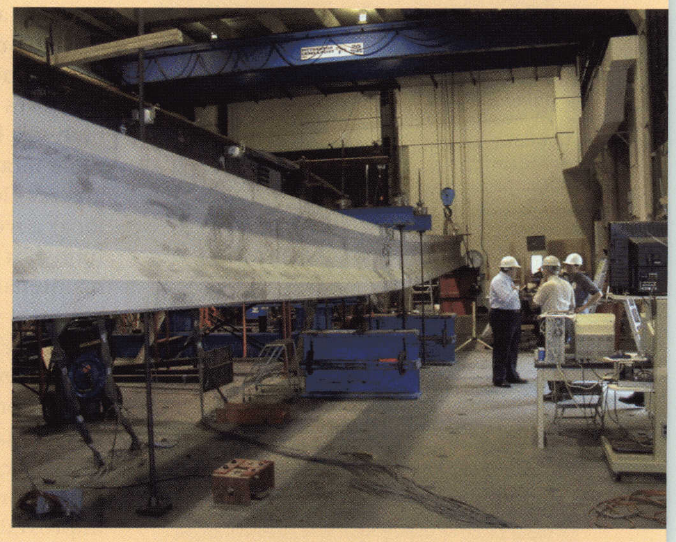
by Steven B. Chase, Sheila Rimal Duwadi, and John M. Hooks

FHWA proposes a research-packed agenda for preserving existing bridges and building new ones.

Bridges, culverts, and tunnels are the glue that holds the surface transportation network together. Whether designed for motorists, pedestrians, bicyclists, or trains, these structures safely convey travelers above and beneath waterways, through mountains and cities, and across the Nation's varied landscapes.

The Federal Highway Administration (FHWA) is committed to delivering a safe and cost-effective bridge infrastructure to support America's highways. To meet the demand for a 21st century transportation network, FHWA is proposing a robust and aggressive research and technology (R&T) program to preserve the aging and deteriorating U.S. bridge infrastructure and advance new technologies for designing stronger, longer-lasting bridges. Unofficially termed Bridges for the 21st Century, the program will build on and expand the programs pursued under the Transportation Equity Act for the 21st Century (TEA-21) and previous R&T programs.

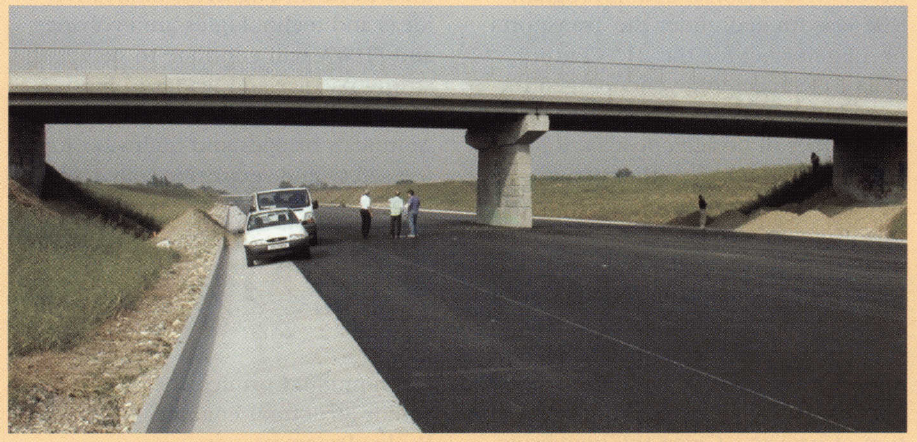
"FHWA, in partnership with the States, will be developing and deploying innovative technologies," says Raymond McCormick, senior structural engineer in FHWA's Office of Bridge Technology, "that enable us to get out ahead of the bridge deterioration curve and stay there."



Researchers at the Turner-Fairbank Highway Research Center in McLean, VA, are conducting research on this bridge girder composed of ultrahigh-performance concrete.

Three Program Thrusts

To meet current and future needs for bridge research and technology, the Bridges for the 21st Century program will have three major thrusts. The first involves stewardship and management of the current bridge inventory to ensure economical, safe, and continuing service.



Engineers in France constructed this bridge using ultrahigh-performance concrete.

The second thrust centers on ensuring the safety and reliability of bridges by improving their ability to resist the impacts of extreme events such as earthquakes, flooding, vessel or vehicle collisions, and intentional attacks.

The third research area involves developing a new generation of cost-effective, high-performance, and low-maintenance bridges. FHWA envisions a new paradigm in design and construction that results in bridges that are built faster and cheaper, require little or no maintenance, and feature a minimum 100-year lifespan.

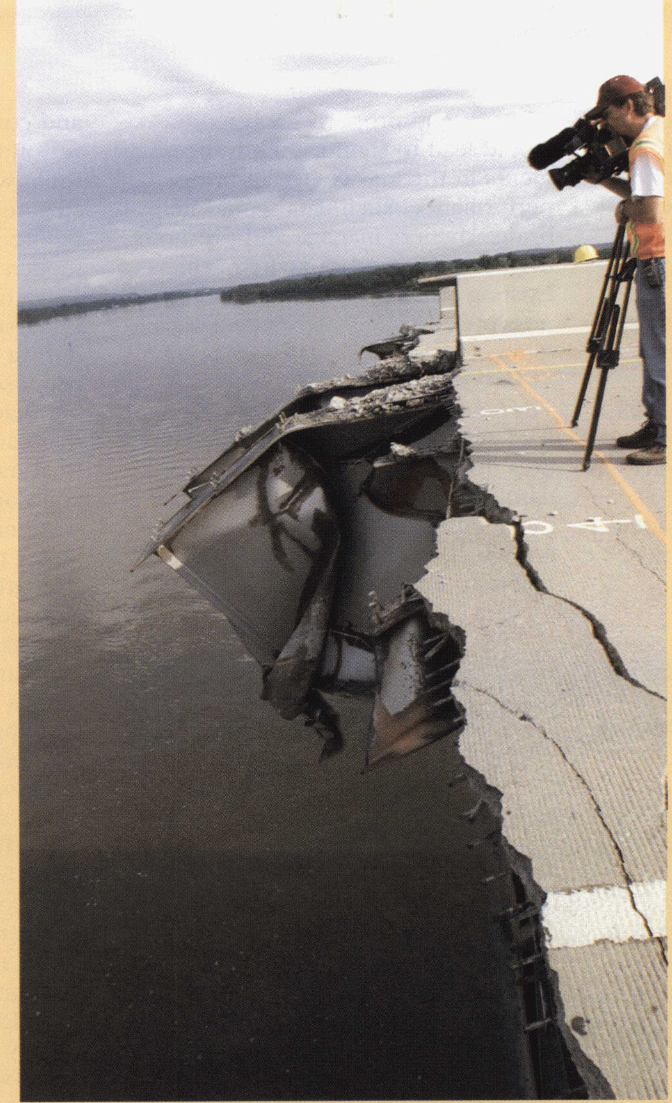
Focus on Preservation

The National Bridge Inventory shows that more than 480,000 bridges and 110,000 tunnels and culverts serve U.S. highways. The average age of existing bridges is 42 years and rising. In the coming decades, new bridges will replace many of these spans, but in the meantime, bridge owners need cost-efficient ways to maintain and preserve the existing bridges until they are rebuilt.

FHWA lists nearly 160,000 U.S. bridges as substandard. Although many are rehabilitated and taken off the list annually, about 3,000 others are added to the list each year. More importantly, motorists cross over substandard bridges more than one billion times each day. Between 1982 and 2001, Federal and State agencies made significant progress, reducing the number of substandard bridges from more than 250,000 to fewer than 160,000. But much remains to be done.

Says McCormick, "In the past, many bridge owners neglected the structures until they were beyond rehabilitation and in need of replacement. A primary objective of FHWA's stewardship and management focus is to encourage bridge owners to place more emphasis on system preservation based on proven preventive maintenance and rehabilitation techniques."

Future stewardship and preservation will require new research and technology, as well as innovative tools, strategies, and management practices. Researchers, for example, need to understand the micro- and macro-level mechanisms that cause bridge materials and elements to deteriorate physically, limiting the service life of bridges.

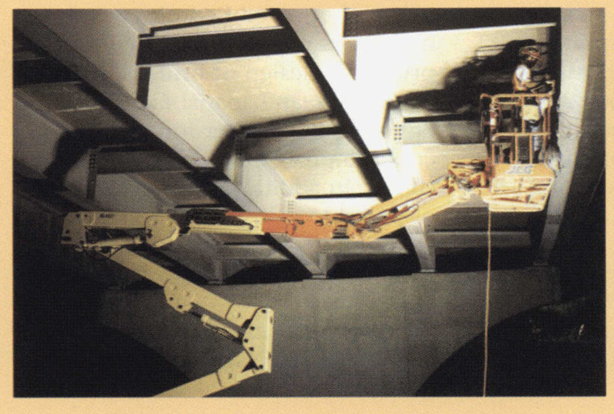


Oklahoma DOT

In May 2002 a barge smashed into the piers of a bridge on I–40 in Oklahoma, causing the structure to collapse. Here, a television cameraman shoots footage at the edge of the smashed bridge deck.

To evaluate and quantify the condition of bridges and their components, the transportation community needs to provide inspectors with improved technologies such as nondestructive testing, remote sensing techniques, and global monitoring. Improvements also are required for the quality, accuracy, and precision of quantitative information on bridge conditions, such as element-level data that support improved decisionmaking processes and tools for bridge management.

The transportation community also must provide breakthroughs in technologies for repairing and rehabilitating bridges quickly to minimize the duration and public impact of work zones. Other research needs include technologies for detecting the condition of bridge decks at highway speeds and methodologies to assess the condition of concrete decks with overlays. Finally, improved modeling for life-cycle cost analyses could lead to cost-effective strategies and techniques for preventive maintenance that extend and optimize service life.



A worker installs instrumentation beneath a bridge ramp in Utah as part of a research project on curved steel bridges.

Collecting Data

Stewardship and management activities depend on reliable, quantitative data on bridge conditions and the factors that influence performance and deterioration. At present, the data are unavailable, or not available in a format suitable for analysis. A key component of the Bridges for the 21st Century program, therefore, deals with data collection.

FHWA proposed a Long-Term Bridge Performance program that would gather data to support improved methodologies, tools, and programs for bridge preservation and management. The 10- to 20-year program would monitor 1,000 to 2,000 carefully selected bridges representing a cross-section of the existing infrastructure in terms of type, span length, construction materials, traffic volumes, climatic and environmental conditions, and maintenance practices.

The data set for each bridge would start with all available baseline information including design codes, material specifications, as-built plans, and any relevant history of maintenance and major rehabilitation. FHWA would work with highway agencies participating in the program to keep detailed records of maintenance needs, document all system-preservation activities, and track costs.

Federal Emergency Management Administration

An earthquake damaged this bridge span in Northridge, CA, on January 17, 1994.

Each bridge would be instrumented and monitored to collect research-quality data on factors that influence deterioration and affect performance. Wherever feasible and appropriate, FHWA and program participants would deploy advanced bridge-inspection technologies, such as ground-penetrating radar for evaluation of bridge decks. They also would record quantitative data on changes in bridge conditions, including delaminations in concrete decks or corrosion losses in the webs and flanges of steel girders. In addition, they would track operational characteristics such as crashes and congestion on the bridges being monitored.

This quantitative data, collected for thousands of bridges over 10 to 20 years and properly analyzed, would lead to significant advancements in the knowledge of bridge performance. Such data would help bridge owners manage and preserve the condition and capacity of the existing infrastructure at the least-possible cost.

Natural Disasters

The second focus of the proposed R&T strategy deals with bridge failures due to catastrophic events, both natural and manmade. The goal of this focus area is to deliver the knowledge and technologies that will help ensure that the Nation's bridge infrastructure continues to function safely and reliably, even during extreme or infrequent catastrophic events.

Natural disasters like earthquakes and floods have a high probability of affecting large areas and a large number of highway structures simultaneously, significantly disrupting mobility, emergency response, and local economies. With each major event, engineers learn new lessons about bridge response and performance, and new standards and technologies often follow. Through the Bridges for the 21st Century program, FHWA proposes continued and expanded research in several key areas.

Earthquakes. The seismic research program at FHWA developed and continues to refine guidance for retrofitting existing bridges to help them withstand earthquakes. At-risk structures include all bridges built before 1980 in regions that have moderate to high seismic activity.

To help researchers and engineers understand how structures react during earth movements, FHWA has proposed developing and installing more accurate position monitors that can determine the relative and total movement of critical bridge components. During post-event assessments, inspectors need to have better tools to evaluate the residual strength and structural integrity of damaged sections. New technologies, like the shape-memory alloys that can return to their original shapes after they are deformed, may find application in cable restrainers and seismic isolation bearings.

Floods. Approximately 85 percent of the structures listed in the National Bridge Inventory cross waterways. In the United States, flooding and scour cause more bridge collapses than all other causes combined. FHWA, therefore, has an active program to study the hydraulics and hydrology of bridge structures. The agency has a state-of-the-art hydraulics laboratory where researchers conduct scale-model tests. Through a series of hydraulic engineering circulars published by the FHWA Hydraulics Laboratory and an ongoing training course offered by the National Highway Institute, FHWA helps States and consultants evaluate and mitigate the effects of scour.

Engineers need improved techniques for physically and numerically modeling unique scour problems and accounting for exposure to various flood levels over the life of a bridge. They also need advanced monitoring systems to record the depth of scour during individual events. Improved hydrology and hydraulics research could help improve the design of bridges in tidal waterways, and spatial radar technology used in weather forecasting could improve predictions of flood runoff. In addition, the development of portable instrumentation is critical to assess foundation damage before reopening a bridge after a major flood.

Wind. Since the dramatic collapse of the Tacoma Narrows Bridge near

Tacoma, WA, in 1940, the effect of wind on structures has become a significant concern for bridge owners. FHWA is confronting wind-induced hazards by developing comprehensive guidelines for designing and retrofitting bridges, creating specifications for assessing the aerodynamics of new designs, and identifying a rational method for wind-climate analyses. Researchers will conduct extensive experimental and analytical work relative to vortex-induced vibration of bridge decks. In addition, they will study the wind- and rain-induced vibration of bridge cables and explore aerodynamic surface treatments. FHWA also is considering the development of a suite of software tools to analyze the effects of wind and vehicle gusts on support structures.

Other Threats

Transportation agencies and the driving public expect highway and bridge infrastructure to withstand everything from the normal wear and tear from years of service operation to unanticipated events like collisions, fires, and acts of violence.

Overloads. Today, trucking accounts for 80 percent of expenditures on freight transportation in the United States. In May 2002, the Transportation Research Board (TRB) released a study that suggests reforming size and weight regulations to allow larger trucks on roadways. The report, *Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles—Special Report 267*, recommends a program of basic research to determine fact-based regulations for truck size and weight.

These factors have a significant impact on maintenance and construction costs for highway pavements and bridges. Research is necessary to assess the ability of existing bridge structures to carry heavier loads. The large percentage of bridges identified as functionally obsolete also presents a challenge if trucks exceed weight or size limits, posing potential structural and safety risks.

Collisions. In May 2002, a barge struck an unprotected pier on a bridge on I-40 in Oklahoma, collapsing the bridge and killing 14 people. For bridges over navigable waterways, the piers are the most vulnerable elements to damage from vessel collisions. Therefore, in heavily trafficked rivers with ships and large barges, bridge owners should protect piers and install monitors to track movements caused by collisions. Design codes should be revised to provide more effective provisions for collisions involving commercial crafts or enemy vessels.

To reduce the impact of vehicle collisions on bridges, FHWA is conducting crashworthiness tests on barriers. More research is necessary to improve analytical capabilities of predicting the performance of barriers during impacts. Researchers at FHWA are employing finite element analysis to predict the crashworthiness of various concrete barrier shapes and developing mathematical formulas that describe the outcomes of crash testing without the need for multiple full-scale crash tests.

Fire. Although fires damage all types of highway infrastructure, fires in bridge tunnels often are more dangerous to motorists and disruptive than those on bridges and overpasses. Following the tragic fires in the Mont Blanc and Tauern tunnels in Europe in 1999, highway agencies began devoting renewed attention to fire safety.

FHWA proposes further study of the properties of materials, especially high-performance materials, at elevated temperatures. Researchers must determine the temperatures generated by the combustion of large volumes of flammable materials, such as gasoline, diesel fuel, liquid propane, and rendered animal fat. Based on heat input and temperature gradients, they can verify the immediate and hour-by-hour effects of exposure on the structural properties of materials. As with the other hazards, guidelines are needed to assess the remaining strength of fire-damaged structures and develop rapid-repair techniques.

National Security. More than 2 years after the tragic events of September 11, 2001, transportation agencies continue to define strategies to protect the Nation's highways and bridges from acts of violence. To develop a resilient physical infrastructure that can withstand these large-scale strikes, researchers need to understand the threats, identify specific vulnerabilities, and develop technologies to help eliminate or protect against these vulnerabilities. Engineers need better methodologies for assessing the safety and residual capacity of structures after an incident, and new techniques for repairing and restoring bridge infrastructure quickly.

In this area, FHWA proposed that the R&T program covers systems analysis and design, material improvement, detection and surveillance, post-event assessment, repair and restoration, and evaluation and training. Also, FHWA is partnering with the defense community to draw on the military's knowledge and experience and will transfer applicable technologies.

Trends in Bridge Design

In addition to managing the existing bridge inventory and identifying strategies to protect structures from natural and manmade hazards, FHWA also plans to develop a new generation of high-performance bridges.

Nationally, highway agencies build, replace, and rehabilitate about 10,000 bridges per year, but the majority of these new bridges are designed and constructed using today's technologies. New materials and methods are necessary to counter or mitigate the impact of deterioration processes in new structures, structural elements, and existing bridge members.

The demand for increased mobility, reduced congestion, enhanced safety, and improved homeland security will present unprecedented challenges for transportation agencies in the coming years. Only time will reveal the exact geometric and material characteristics of tomorrow's bridges, but the National Bridge Inventory offers some definite trends. For example, data from 1985 to 2001 show steady increases in span length (19 percent), overall structure length (15 percent), and deck width (13 percent). Longer span lengths stretch the limits of existing materials to gain the maximum economy of scale and simultaneously reduce the environmental impact of structures.

Higher traffic volumes and increasing safety concerns contribute to the increase in deck widths. "In the future, bridges will carry heavier loads and more traffic," says

Bridge Design Classifications

Superstructure Material	Design Type	Number of Bridges
Prestressed Concrete	Stringer	4,376
Steel	Stringer	3,936
Prestressed Concrete	Multibox	3,593
Steel	Continuous Stringer	1,790
Reinforced Concrete	Continuous Slab	1,707
Prestressed Concrete	Continuous Stringer	1,667

Recent FHWA research revealed that of the more than 33,000 new bridges constructed in the United States between 1996 and 2000, two-thirds fell into one of six design classifications based on material (concrete or steel) and design types. *Source: FHWA*

Myint Lwin, director of the Office of Bridge Technology at FHWA. "More lanes and wider bridges help accommodate increased traffic, and broad shoulders make it safer for motorists to change a flat tire or for incident response teams to handle emergencies."

Engineers typically design bridges to carry a 32,660-kilogram (72,000-pound) load (HS-20). In 1985, 1 out of every 50 bridges was designed to accommodate a 40,820-kilogram (90,000-pound) load (HS-25). By 2001, agencies were designing 1 in 5 bridges for an HS-25 load. "These trends clearly indicate that we will expect more performance from bridge materials and systems in the future," says Lwin.

To evaluate the market potential for the bridges of the future, FHWA recently conducted a detailed analysis of the more than 33,800 new bridges that were constructed in the United States between 1996 and 2000. The goal was to define the most promising systems to pursue and develop. The study showed that two-thirds of the bridges fell into one of six design classifications. (See "Bridge Design Classifications.") The study also revealed that these common bridge types show definite geographic clustering in different regions of the country and that most of the bridges have maximum span lengths of 30 meters (100 feet) or less.

Based on these findings, FHWA concludes that existing market conditions support a strategic research focus on a few standard bridge types, simple spans (less than 30 meters), and standardized bridge systems that can be manufactured in significant numbers and distributed regionally.

Bridges of the Future

FHWA identified several specific performance goals to guide the agency's proposed research initiative. These goals, which account for initial costs, service-life costs, and indirect costs like time and safety, are as follows:

- Design structures that resist corrosion and require little or no structural maintenance.
- Reduce life-cycle costs significantly through the use of enhanced materials and processes.
- Construct bridges in such a way that they can be widened quickly and easily, or adapted to meet new traffic demands.
- Help elevate the immunity of structures to floods, earthquakes, fire, wind, fracture, corrosion, overloads, collisions, and acts of intentional violence through the application of new materials and techniques.
- Integrate sub- and superstructures and eliminate vertical and lateral clearance problems in newly designed bridges.

Wider acceptance and implementation of best practices and innovative techniques, such as using precast or prefabricated components and employing integral abutment construction, can help attain several of these performance goals. Also critical is developing and delivering *bridge systems* rather than separate foundations, substructures, superstructures, and decks. Moving toward widely adopted standards for design and construction can help State highway agencies take advantage of the economies of scale that manufacturing offers.

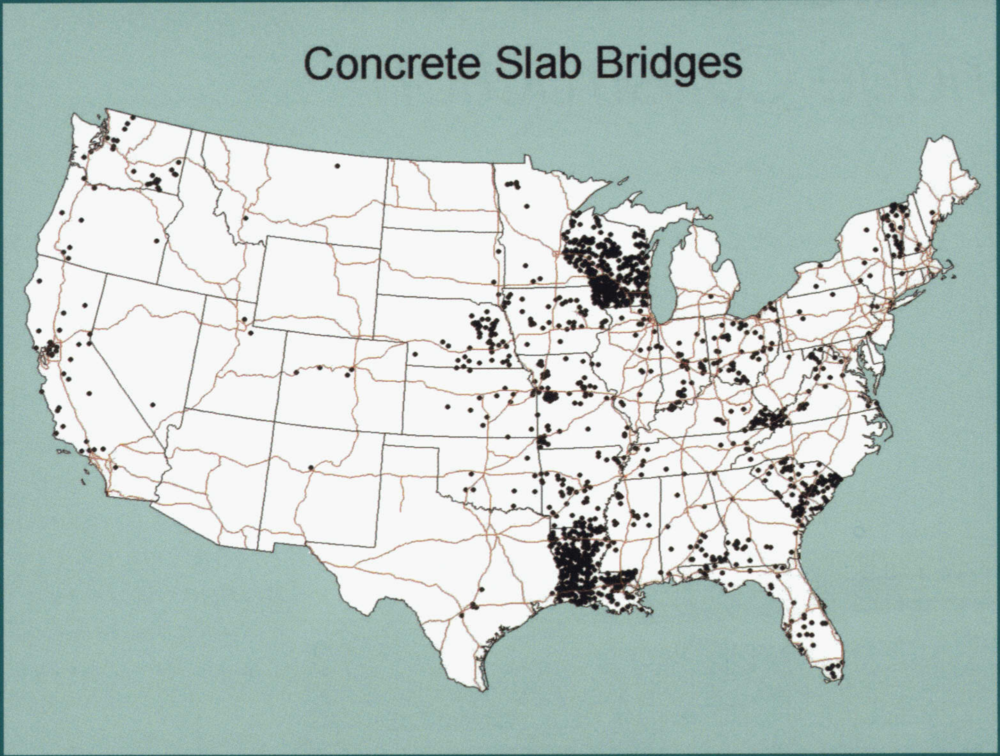
"We recognize that these goals will seriously stretch our creative and technological capabilities," says King W. Gee, associate administrator in the Office of Infrastructure at FHWA, "but we plan to build on a decade of research in high-performance materials and seriously pursue the development of structural systems that will meet these performance objectives."

Getting the Word Out

Another critical aspect is sharing the results of the R&T program. Since 1998, the Innovative Bridge Research and Construction (IBRC) program successfully promoted the use of innovative materials and technologies in constructing new bridges and repairing, rehabilitating, or replacing existing ones. But implementation under the IBRC program has been characterized by small, usually incremental steps, such as replacing steel reinforcement with polymers or standard concrete with higher-performing concrete. FHWA plans to broaden and redirect the IBRC program to become the primary mechanism for transferring new technologies to the States.

FHWA has proposed replacing the IBRC with a new program called the Innovative Bridge Research and Deployment (IBRD) program, which will have a goal of spurring the development of new and innovative bridge systems. The new program will expand the scope of the IBRC program to include new structural systems and technologies for strengthening, repairing, rehabilitating, and preserving bridge infrastructure.

According to Lwin, the emphasis of the IBRD program will be on deploying and evaluating technolo-



This map shows the location of the 1,586 concrete slab bridges that were constructed in the United States between 1996 and 2000. The regional clustering in Louisiana and Wisconsin indicate market opportunities for standardized production and distribution of bridge systems.

Source: FHWA National Bridge Inventory

gies that are likely to become new standards in the future. "We plan to emphasize the development and evaluation of technologies that have potential application on thousands of bridges," he says, "not just a few."

FHWA also plans to launch several demonstration projects to introduce new bridge technologies. The demonstration projects will include both educational and hands-on elements to help move technology from the laboratory into practice.

Committed to Safety

FHWA's proposal to refocus and revitalize the R&T program sets a strategic direction for developing and deploying breakthrough technologies to deliver Bridges for the 21st Century.

"In the pursuit of the bridge of the future, we must not lose sight of the need to manage the existing bridge inventory effectively and efficiently," Lwin says. "Once FHWA and our partners in the States and private sector develop the new technologies, we will engineer the Nation's bridges to meet the new demands for safety, security, reliability, and durability."

Steven B. Chase has more than 25 years of experience with FHWA and has worked in the Office of Infrastructure Research and Development since 1992. As technical director for bridges, Chase oversees all research and development activities related to highway structures. He is founder and past chairman of TRB's Subcommittee on Nondestructive Evaluation of Bridges. Chase has a bachelor's degree in civil engineering from the University of Hartford, a master's in civil and environmental engineering from The George Washington University, and a Ph.D. in philosophy and civil and environmental engineering from the University of Rhode Island.

Sheila Rimal Duwadi manages several research programs, including bridge and tunnel security and timber bridges, in the FHWA Office of Infrastructure Research and Development at the Turner-Fairbank Highway Research Center (TFHRC). Duwadi chairs the Technical Committee on Timber Bridges at the American Society of Civil Engineers and is an associate editor for the society's *Journal of Bridge Engineering*. She is a member of TRB's Committee on General Structures and the American Association of State Highway and Transportation Officials' Subcommittee on Bridges and Structures. Duwadi is a registered professional engineer in Virginia.

John M. Hooks is the team leader for the Inspection and Information Management Team and director of the Bridge Management Information Systems Laboratory at TFHRC. He also manages the IBRC program. Hooks has spent 26 years at FHWA headquarters and TFHRC helping develop and implement innovative bridge technology and management systems. Before coming to the Washington, DC, area, he served as assistant division bridge engineer in the FHWA New York Division Office. Hooks has a bachelor's degree in civil engineering (1966) and a master's degree in structures (1968) from Clarkson University.

For more information on bridge research at FHWA, visit www.tfhrc.gov/structur/structre.htm.

Laying the Groundwork *for Fast Bridge Construction*

by Mary Lou Ralls and Benjamin M. Tang

Prefabricated elements and systems accelerate construction of bridges to hours or days instead of months or years.

In February 2003, more than 200 bridge professionals viewed successful projects at the National Prefabricated Bridge Elements and Systems Conference cosponsored by the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA). The presenters shared visions of bridges built in hours or days as opposed to months or years. Bridge engineers from 35 States and representatives from AASHTO and FHWA, professional associations, contractors, suppliers, and academia listened as the speakers described projects that met the need of State transportation agencies to "Get In, Get Out, and Stay Out."

The Nation's bridges have a median age of 40 years, and today many structures need reconstruction. But increased traffic and urban congestion demand outside-the-box thinking to accelerate construction. In 2001 the AASHTO Technology Implementation Group, known as the TIG, chose prefabricated bridge elements and systems as one of the innovative technologies that promises the highest payoff. (Others include accelerated construction and intelligent traffic systems in work zones.) To encourage implementation of bridge prefabrication, the AASHTO group sponsors workshops, provides speakers for related conferences and other meetings, and publishes a Web site (www.aashtotig.org) that includes information on a number of prefabricated bridge projects that have been constructed to date.

(Above) Two cranes lift a preconstructed unit into place on the James River Bridge in Richmond, VA. *Photo: URS Corporation.*

In addition, FHWA, through its Innovative Bridge Research and Construction program and the Resource Center, champions prefabrication for accelerated construction. "Our vision is to get out in front of the bridge deterioration curve with accelerated construction such as prefabrication and stay there," says Tom Saad, structural design engineer, FHWA Resource Center, Chicago. "FHWA bridge engineers will partner with States, industry, and academia to develop and implement technologies that produce more durable highway structures that can be constructed in a fraction of the time of conventional structures."

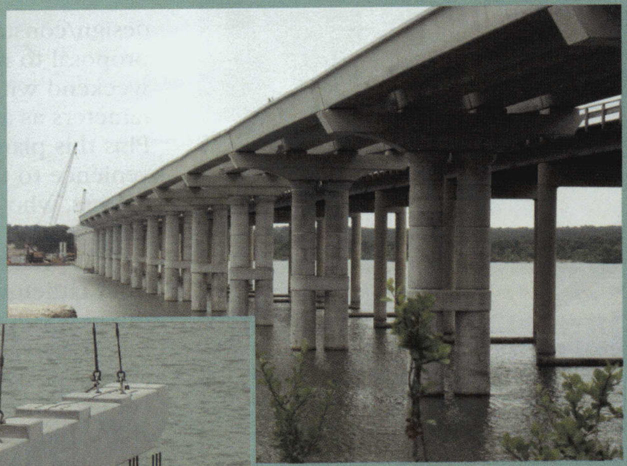
The AASHTO group and FHWA are encouraging this technology because of the many advantages for bridge owners, engineers, builders, and the traveling public. First, use of prefabricated elements or systems minimizes traffic impacts. For example, contractors can perform time-consuming formwork assembly, concrete casting, and curing offsite in a controlled environment away from traffic. Prefabricated bridge designs are more constructible because the offsite work reduces time onsite dealing with constraints such as heavy traffic, extreme elevations, long stretches over water, and tight urban work zones.

Safety improves because prefabrication reduces the exposure time for workers and the public who travel through construction zones. Prefabricated elements and systems work well to accelerate both reconstruction and new construction. Prefabrication and shipment of components to the job site also reduce impacts on the environment. Finally, prefabricating takes elements and systems out of the critical path of the project schedule. The fabricator can take as much time as needed to produce a quality component or system in a controlled environment. Improved quality translates to lower life-cycle costs and longer life.

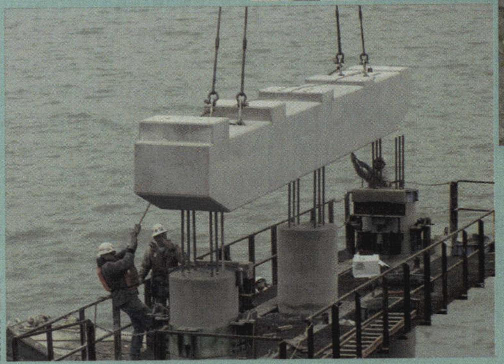
With traffic control running anywhere from 20 to 40 percent of construction costs and user delays priced at thousands of dollars per day in heavy traffic areas, States and owners will realize cost savings from accelerated bridge construction. Then as the technology becomes standard practice, costs will decrease.

The conference showcased a wide range of bridges of all sizes. Five outstanding prefabricated bridges presented here are Lake Ray Hubbard in Dallas, TX; James River in Richmond, VA; Baldorioty de Castro Avenue in San Juan, Puerto Rico; Mitchell Gulch in Castle Rock, CO; and Reedy Creek Bridge in Orlando, FL.

For this precast bridge in Lake Ray Hubbard in Dallas, TX, prefabrication was quick and cost-effective.



Texas DOT



Texas DOT

Workers lower a precast bent cap at Lake Ray Hubbard.

Lake Ray Hubbard, Dallas, TX

With Texas containing one-twelfth (approximately 49,000) of the Nation's bridges, the Texas Department of Transportation (TXDOT) has experimented with prefabricated elements for decades. The agency now is expanding its use of prefabricated elements to include entire systems. On the eastbound two-lane Lake Ray Hubbard Bridge, the contractor took one look at the power lines just 14 meters (45 feet) from the work zone and decided that the combination of a rocking barge and a crane's mast arms posed an unacceptable risk. Because the bridge's 43 pier caps had repeating elements, prefabrication could be cost effective.

TXDOT engineers designed the caps that extend between the supporting columns, and the contractor built a portable trestle to construct the 1,312-meter (4,300-foot)-long bridge. The defined work area from the trestle placed every component in the critical path so prefabricating the caps was crucial to maintaining the schedule, according to Tracey Friggle, TXDOT assistant director of construction for the Dallas District and project manager. "Without the prefabricated pier caps, the work would have taken us an extra year," Friggle explains. "Instead of 8 to 9 days to form, tie, pour, and cure each cap, we took 1 day to set each one."

To anchor the precast caps to the existing columns, crews used vertical grout sleeves cast into the caps and then pumped a high-strength grout into the sleeves to complete the connection.

James River, Richmond, VA

"Today engineering is the easy part, while traffic is a big consideration," says Malcolm Kerley, Virginia DOT's chief engineer for program development. "The I-95 bridge over the James River carries 110,000 vehicles a day, so we wanted to open it to the public as soon as possible."

After considering public input, VDOT closed the lanes from 7 p.m. to 6 a.m. Sundays through Thursdays for construction. The agency also requested A plus B bidding, with "A" being the unit price and "B" the number of days valued at $30,000 per day. VDOT did not consider any bids over 220 days. The winning contractor bid 179 days and ultimately finished in 140 days. For each day under 179, the contractor received a $30,000 bonus, and for each day over was to have been charged $30,000. Because daytime opening was critical, VDOT established a schedule of disincentives for time beyond 6 a.m. in restoring all traffic lanes. Fines ranged from $5,000 for failure to open at 6 a.m., an additional $10,000 if not open by 6:15 a.m., $35,000 if not open by 6:30 a.m., and so on to a cumulative disincentive of $250,000 for remaining closed until 6 p.m.

For most of the 101 spans, the contractor erected preconstructed composite units consisting of a 222-millimeter (8.75-inch) deck over steel plate girders. A nearby casting yard precast the units. Overnight, the work crews removed the old bridge span, prepared the gap for the new preconstructed composite unit, set the unit in place, sealed slab joints, and post-tensioned slabs transversely.

Baldorioty de Castro Avenue Bridges, San Juan, PR

This Puerto Rico project, which was highlighted at the conference, demonstrated how to deliver urban bridge projects in weeks instead of months or years using prefabrication methods. The contractor, with exacting sequencing, pieced together the two totally prefabricated overpasses in just two weekends.

To ease congestion on a San Juan road that carries more than 100,000 vehicles per day, the engineering contractor designed the prefabricated overpasses at two intersections for the San Juan Department of Transportation and Public Works. The construction contractor erected two 275-meter (900-foot)-long and two 214-meter (700-foot)-long totally prefabricated bridges in two stages.

On the first weekend, the crews drove piles, cast the footings in place, and then installed asphalt over their work. The next weekend the crews uncovered the footings and erected and post-tensioned the prefabricated substructure components.

URS Corporation

For the James River Bridge, the Virginia DOT post-tensioned this hammerhead pier cap to carry the construction loading.

After the crews completed the first two substructures, they set the 30.5-meter (100-foot)-long superstructure span in place, complete with seven box beams, wearing surface, and parapets.

Two work crews erected the remaining spans simultaneously from the center span toward each end, post-tensioned each transversely, and then placed an asphalt overlay. To complete the process, the crews constructed retaining walls with select fill on the approaches. The first 275-meter (900-foot) overpass was ready for traffic in 36 hours, and the second overpass in just 21 hours.

"Commuters traveled at grade on Friday evening, and by Monday morning they were traveling over the new overpasses," says John Dick, conference presenter and structures director for the Precast/Prestressed Concrete Institute in Chicago.

Mitchell Gulch, Castle Rock, CO

Plans by the Colorado Department of Transportation (CDOT) specified a cast-in-place box culvert to replace a 49-year-old deteriorated timber structure rated as one of Colorado's 10 worst bridges. But when the Denver-based contractor examined the long grade leading down to the Mitchell Gulch Bridge and the resulting dangerous detour, he decided that he could replace this 12-meter (40-foot)-long bridge in a weekend instead of a couple of months.

On a previous project with the same conditions, the driver of an 18-wheeler coming down the hill had lost brakes on 14 of the wheels, crashed through the barricades, and killed two employees. Two contractors approached CDOT with a value design/construction engineering proposal to replace this bridge in a weekend within the same cost parameters as a conventional project. Plus this plan would minimize inconvenience to the 12,000 daily commuters, who had no reasonable alternative route.

The prefabrication manufacturer from Littleton precast 90 percent of the new bridge, including substructure units such as wing walls and abutment walls, along with the more common precast deck units to enable rapid assembly. The contractor prepared steel piles to support the precast substructure units ahead of time. The contractor and engineering manager orchestrated every minute of the weekend with contingency plans such as backup equipment servicing, leaving little to chance. The contractor made field adjustments on several prefabricated elements.

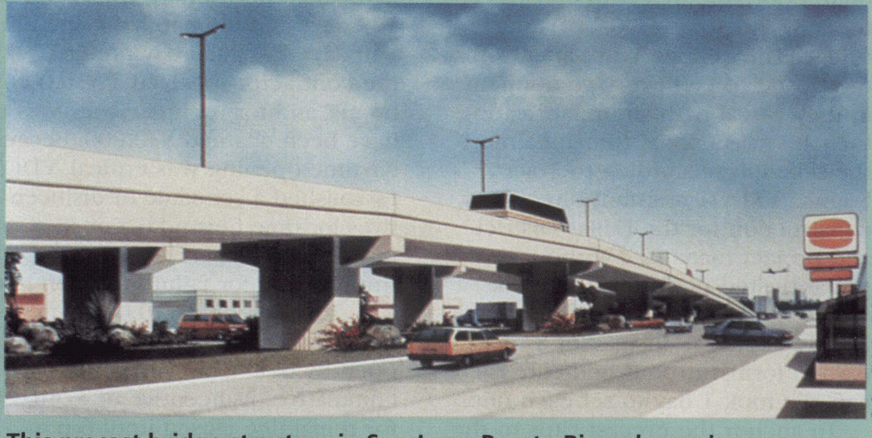
At 7 p.m. on a Friday, the contractor rerouted traffic and began dismantling the old structure. By Saturday at 1 a.m., crews had placed abutments and wing walls, and welded them to the steel piles and to each other. When a fiber-optic line was encountered, the construction team adjusted the angle of the wing walls to accommodate the line. At the same time, crews rehabilitated the streambed with riprap. On Saturday afternoon, after placing the flowable fill behind the abutment walls, the team lowered, grouted, and post-tensioned the precast girders. Work stopped at 11 p.m. so the crew could rest and then resumed Sunday at 7 a.m. The crew completed the earthwork, backfilling, and asphalt paving on the bridge and approach, opening the structure by 5 p.m. in a record 37 hours of actual construction.

Reedy Creek Bridge, Orlando, FL

To mitigate the environmental impacts of heavy equipment on the Reedy Creek wetlands at the Animal Kingdom Entrance to Disney World, Walt Disney Imagineering committed to a top-down construction process using precast pile caps, prefabricated deck planks, and steel pipe piles. The Reedy Creek Bridge has two parallel 305-meter (1,000-foot)-long bridges widening from 13-meters (43 feet) for the first 73 meters (240 feet) to 16 meters (53 feet) wide for the remainder. Utilities cross Reedy Creek in a 4.3-meter (14-foot) gap between the two bridges.

The selected contractor won the project with a design that resulted in net savings of $950,000 on the $8.3 million project. The design met Florida Department of Transportation standards, maintained the bridge span and roadway deck configuration, reduced the number of support piles, and simplified the precast pile caps. In addition, the design used 2-meter (6-foot)-wide deck panels that are 381 millimeters (15 inches) thick at the center and 610 millimeters (24 inches) thick at the ends instead of 457-millimeter (18-inch) constant depth panels.

The contractor drove the steel piles and erected precast compo-



John Dick, PCI

This precast bridge structure in San Juan, Puerto Rico, shown in an illustration, was erected from the ground up in just 21 consecutive hours.

nents from a traveling erection platform. The 104 pile caps are identical except for the length and number of conical holes (two or three) for integration with the steel pipe piles. Shear keys between panels and the reinforced concrete overlay are the only cast-in-place concrete. Traffic barriers were slip-formed.

What Needs to Change?

These accelerated prefabricated bridge projects illustrate a change in thinking from the traditional approach to a systems approach that considers traffic impacts during the planning stage.

"Contracting procedures need to change to provide incentives for contractors to build bridges rapidly," Dick observes. "Whether it's A plus B bidding or other incentive/disincentive programs, the system has to change to encourage innovation."

"To be cost-effective," Rick Lawrence, president of Lawrence Construction Co. from the Colorado project, adds, "I need to build at least 10 bridges at a time, but the State awards projects one at a time." By grouping single-span bridges, both the contractor and the State would realize volume savings in materials and labor. Another option is the design/build approach enabling the contractor to contribute practical ideas for accelerating construction.

Although the States have reaped the rewards of accelerated construction and superior quality with components produced in a controlled environment, some details of this technology can still be improved.


Walt Disney Imagineering

The precast pile caps and deck panels at the Reedy Creek Bridge site.

Kerley cautions, "My concern is not with the quality of the components but with the quality of the connections."

Saad agrees, "We still need research on developing the best practices for delivering this technology."

Ian Friedland, FHWA bridge technology engineer adds, "Some standards and specifications need to be evaluated for accelerated construction."

Looking to the future, Kerley says, "Through the AASHTO TIG we're establishing a network in which one State shares its success, and another State takes the idea and tweaks it for its project."

With the variety of prefabricated systems available, bridges need not be "cookie-cutter" designs, but FHWA and the States are developing standardized designs with modular systems to replace the typical 50-year-old "bread-and-butter" bridges that need replacing nationwide. FHWA's Bridges of the Future initiative envisions a bridge with accelerated construction time, adaptability to widening and other demands, and lower life-cycle costs. Prefabricated bridge elements and systems are a step toward this vision.


Gregg Gargan, CDOT

The contractor installed the precast components for the Mitchell Gulch Bridge in one weekend.

Mary Lou Ralls, P.E., chairs the AASHTO TIG (Technology Implementation Group) on Prefabricated Bridge Elements and Systems. She serves as director of the Bridge Division at TXDOT where she started as a bridge design engineer in 1984. She earned her bachelor's in civil engineering in 1981 and her master's in structural engineering from the University of Texas at Austin in 1984. Since 1996 she has chaired and worked on various committees for AASHTO, the National Cooperative Highway Research Program, and the Transportation Research Board, and published numerous articles on bridge topics.

Benjamin M. Tang, P.E., serves as the senior structural engineer in the Office of Bridge Technology for FHWA and has spent most of his 27-year FHWA career in bridge engineering. He earned his bachelor's in civil engineering from the University of Maryland and his master's in structural engineering from the University of Illinois at Urbana. He serves on various task forces and committees in bridge design and construction engineering. He has published numerous articles on the technology of fiber-reinforced polymer composites for bridges.

For more information, States and professional organizations may request speakers on prefabricated bridge technology for workshops and conferences by contacting Mary Lou Ralls, mralls@dot.state.tx.us, or Benjamin Tang, benjamin.tang@fhwa.dot.gov. Upcoming workshops, conferences, research results, and other opportunities for bridge professionals are announced on the AASHTO TIG Web site www.aashtotig.org, along with links to specific FHWA Web sites on prefabrication and accelerated construction. For information on A plus B bidding, visit www.fhwa.dot.gov/programadmin/contracts or www.ic.usu.edu. For precast prefabricators, check the geographical list of prequalified Precast/Prestressed Concrete Institute members at www.pci.org.

A case study of Case Bridge in Washington, DC, provides some clues about the causes of this kind of structural failure.

by Niket M. Telang and Armin B. Mehrabi

Cracked Girders

Five years ago, a flurry of activity followed the discovery of unexpected cracking in the prestressed girders of the Francis Case Memorial Bridge, an arterial structure spanning the Washington Channel of the Potomac River, in the heart of the Nation's capital. To ensure the safety of the traveling public, the District of Columbia Department of Transportation (DCDOT) with the assistance of the Federal Highway Administration (FHWA) immediately began stabilizing the cracked girders and initiated an indepth investigation to ascertain the cause, prognosis, and whether the structure could be repaired.

The Francis Case Memorial Bridge carries eight lanes of I-395 traffic over one channel of the Potomac River in Washington, DC, connecting the downtown with Potomac Park. An extensive rehabilitation program undertaken in 1994 resulted in replacement of the approach spans of the original bridge with precast prestressed concrete girders made continuous at the piers.

During routine inspection of the bridge in 1998, DCDOT and FHWA discovered large, full-depth vertical cracks on the soffit of the beams, near the first interior pier. The cracks in the concrete were of unusual severity and unknown origin.

"Cracking in prestressed elements is undesirable, of course, since it can affect the safety, integrity, and life of the bridge," notes Joey Hartmann, research structural engineer at Turner-Fairbank Highway Research Center. Hartmann assisted DCDOT with the initial inspection of the problem bridge. Design provisions from the American Association of State Highway and Transportation Officials (AASHTO) prohibit cracking of prestressed concrete structures under service loads.

At the time of the discovery, an FHWA-funded, multiyear applied research study, *Jointless and Integral Abutment Bridges,* on prestressed girders had just been completed. The data from that study, along with adaptation of findings from prior research on the performance of prestressed concrete bridges, helped assess the cause and severity of the Case Bridge cracking problem. The DC transportation agency retained a consulting firm to conduct a field inspection and analytical evaluation, and the consultant identified the prime cause of distress as the restraint conditions for positive moments at the piers—more on this in a moment.

During the investigation, the consultant identified atypical load cases normally overlooked during design that could be the primary cause for such failures. "These designs are susceptible to the undesirable continuity-induced cracking

(Above) Francis Case Memorial Bridge crosses the Washington Channel of the Potomac River in Washington, DC. *Photos: Construction Technology Laboratories, Inc.*

observed on the Case Bridge," says Adrian Ciolko, vice president of the consulting firm Construction Technology Laboratories, Inc., of Illinois. He adds, "And counterintuitive to normal design methods, more strength is not always best when designing the continuous zones over supports."

Background

The multiyear FHWA study, which is being prepared for publication, systematically explored the performance of structures designed according to a widely used but often not clearly understood concept of making concrete and steel simple-span girder bridges continuous for live load. Traditionally, simple-span concrete beams have been made continuous at intermediate supports to serve two key purposes: eliminating joints to reduce maintenance and improve ride quality, and increasing the beam's mid-span capacities for superimposed gravity loads.

The continuity results in inducing negative moments (upward convex deformation) at the intermediate supports due to live load, which typically is addressed by providing reinforcment near the top surface of the cast-in-place diaphragms and slabs at the interior supports.

AASHTO recognizes that under certain types of secondary loading effects, such as creep and shrinkage, positive moments (upward concave deformation) can develop as well. The possibility of positive moments at the interior supports is counterintuitive for most engineers, since most types of loading commonly applied to continuous beam structures typically are gravity-induced and create negative moments at interior supports. Design for positive moments at these locations is generally based on crack control within the diaphragm region of the structure.

Typically, engineers tend to use empirical equations, design charts, standard drawings, or rule of thumb methods for design of the positive moment reinforcement. In the same vein, some may tend to follow the "more is better" philosophy, which suggests that providing more reinforcement than required is considered "conservative." This practice, however, occasionally can result in unexpected and sometimes detrimental effects, as discovered on the Case Bridge.

Severe Cracking

The Case Bridge consists of five prestressed concrete girder spans over Potomac Park, followed by numerous steel multigirder spans over the Washington Channel of the Potomac River. The five prestressed concrete spans, spanning from the south abutment toward the south edge of the Washington Channel, are designated by letters "A" through "E" and consist of approximately 18 to 20 simple-span standard AASHTO Type III prestressed girders. The simple-span girders were made continuous for live loads via a cast-in-place 216-millimeter (8.5-inch)-thick lightweight concrete deck on stay-in-place forms and a cast-in-place diaphragm. Spans A and B were converted to two-span continuous beams, while Spans C, D, and E were converted to three-span continuous beams.

During a routine inspection, DCDOT observed severe vertical cracks adjacent to the intermediate support at Pier B on eight interior prestressed girders of Spans A and B. The observed cracks were mostly vertical, traversed the complete width of the bottom flange of the girder, and, in some cases, traversed the full girder height.

The cracks varied in width from 5 millimeters (0.02 inch) to almost 29 millimeters (1.125 inch) at the concrete's formed surface, with the widest crack located approximately at 1.4 meters (4.5 feet) from the Pier B end of the beam. At the time of the consultant's site visit, the DC Department of Transportation already had shored the cracked girders with steel columns. The outside six girders on either side of the cracked girders showed no visible cracking in the cross-section of the beam. The diaphragm regions of those girders, however, exhibited severe cracking and spalling.

The cracking, especially within the girder cross-section, was of unusual severity and unknown origin, and did not coincide with the commonly recognized distress induced by normal flexural or shear loading. Before attempting to alleviate the problem, however, understanding of why the cracking occurred was essential. The FHWA-funded study on jointless bridges provided a theoretical and experimental basis for uncovering the cause of the problem.

Field Inspection and Measurement of Contributing Issues

The consultant conducted an indepth field inspection and assessment to create a baseline condition profile for the distressed girders and to obtain detailed, specific information about the extent and likely

Construction Technology Laboratories, Inc.

Construction Technology Laboratories, Inc.

One of the larger cracks (above). Severe cracking and spalling at one of the intermediate diaphragms (right).

DCDOT

Closeup of hydraulic temporary support jack.

causes of the distress. The field information collected by the consultant included the crack widths, crack lengths, cambers and deflections, temperature gradients, actual creep coefficients, and coefficient of thermal expansion.

Specifically, the consultant collected this source data by conducting the following activities:

- Crack mapping and detailed crack measurements to ascertain growth, environmental and loading parameters affecting the changes in crack widths, and the extreme limits of the crack widths.
- Thermal measurements to find the actual onsite ambient temperature variations and differential temperature gradients for analytical evaluation of secondary restraint moments at the cracked locations.
- Camber measurements to correlate the changes in girder deformation with the thermal measurements. In addition, the field-measured camber data, in conjunction with camber data archived since the girder fabrication, were used to estimate the ultimate creep coefficient of the girders.
- Beam seat survey and inspection of supports and bearings to ascertain restraint conditions and to rule out the possibility of support movement or settlement as a cause.
- Sample concrete coring to determine the coefficient of thermal expansion for the deck, diaphragm, and the girder concretes. These values were used for the analytical evaluation of the thermal and differential thermal effects on the structural behavior.

Evaluation of the Contributing Issues

The analytical evaluation based on the FHWA-sponsored jointless bridge research and the measured values for creep, shrinkage, and differential thermal analyses made it evident that strong potential existed for the observed cracking and distress under specific combinations of differential thermal loads, concrete creep, and shrinkage properties.

One of the less understood and often overlooked issues in design of simple-span prestressed precast beams made continuous for live loads is the effect of secondary moments on the performance of the structure. Converting a simply supported girder—which is without end constraints and is free to deform—to a continuous girder results in the introduction of restraints in the structural system. The result is restraint-induced moments and shears due to loading or environmental effects. These moments and shears commonly are termed "secondary" effects.

The particular load effects of interest for the Case Bridge investigation were the positive secondary moments, that is, those loads causing tensile stresses and potential cracking at the soffit of the girders at intermediate supports. The magnitude of the positive moment is controlled by the amount of positive reinforcement provided at the support diaphragms. By providing a large amount of positive moment reinforcement at the diaphragms, designers inadvertently make the diaphragm area stronger than the adjacent girder sections, thereby forcing the cracking to occur in far more critical but weaker areas of the girder span.

Analytical investigation showed that the large positive moments generated on the Case Bridge were due primarily to the restraint provided by the positive moment reinforcement. "In addition, we surmised that a compromise in bond properties of the prestressing strands or other factors such as presence of lubricants also could have reduced the effective prestressing force at the end of the positive moment reinforcement within the girder cross-section," says Ciolko, "thereby creating an unusually weak section susceptible to cracking under the applied moments."

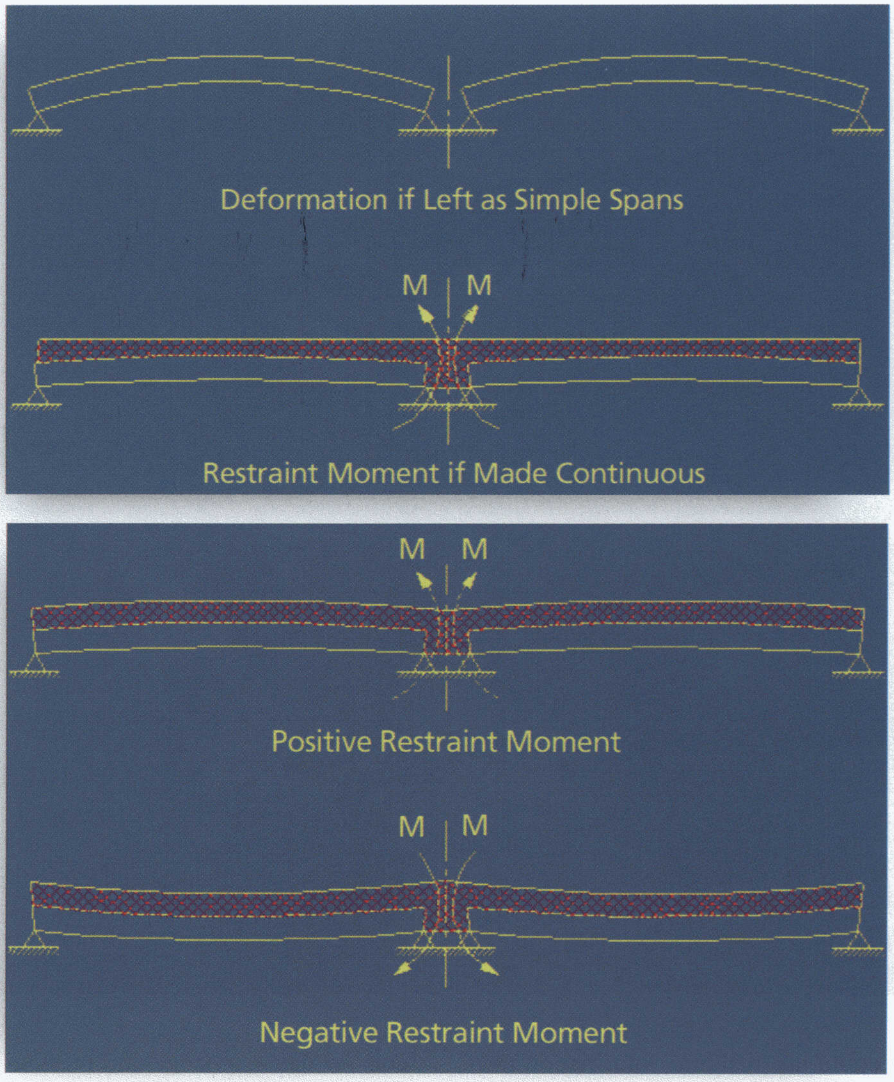
On the girders that did not display cracking along the span, cracking and spalling occurred in the diaphragm regions. "We inferred that inadequate laps in positive moment reinforcement and the cracking and spalling in the diaphragm area resulted in release of the restraint conditions at the supports," says Dr. Ralph Oesterle, the consulting firm's program manager for the FHWA-funded jointless bridge research study, "thus preventing the cracking from occurring within the spans of those girders."

Potential Fatigue Concerns

Temperature differentials between the top and bottom of a bridge structure subject the prestressed beams to cycles of varying restraining moments, resulting in the opening and closing of cracks. This action concentrates stresses in the prestressing strands that cross the crack, which can result in two different degradation mechanisms. In the first mechanism, the stress variation can lengthen the debonded surfaces of strands adjacent to the crack surfaces, reducing available prestress in other sections and initiating additional flexural cracks on either side of existing cracks. In that case, the strands will experience lower variation in the stress range. In the other mechanism, the bond may stay intact while the strands may experience higher stress variation and a reduced fatigue life. In either case, the service life of the structure potentially could be shortened.

Conceptualized Rehabilitation Options

Of primary urgency was the immediate shoring of all the girders that were cracked or showed imminent potential for similar distress. At the time of the consultant's inspection, most of the girders already had been shored. The consultant recommended that additional girders susceptible to similar distress should be shored to ensure the immediate safety of the structure. "This approach allowed DCDOT to pursue



Construction Technology Laboratories, Inc.

These schematics show deformation if spans are left as simple spans, and restraint moments if they are made continuous. The second schematic shows positive and negative secondary moments caused by restraint.

other more robust permanent rehabilitation options pending availability of sufficient funding," says FHWA's Hartmann.

Another problem to be resolved before design of a retrofit was the elimination or minimization of the prime cause of the original distress. Although the majority of beams were not cracked, the positive moment detail at the piers had the potential to create substantial restraint in the future, thereby causing cracking similar to what had already occurred.

"In view of this problem, we considered it advisable to recommend modification of the positive moment connection details by eliminating or reducing the number of positive moment reinforcing bars in the diaphragm region," says Oesterle. The reduction would decrease the positive moment capacity at the diaphragm, thus reducing the magnitude of possible restraint. The crack therefore would form in the positive moment region of the diaphragm, rather than in the girder section.

In addition to immediate shoring and modification of the positive moment reinforcement details, the cracked beams will need to be replaced or rehabilitated to ensure public safety in the long term. DCDOT recently initiated a project to explore options to restore the shear and flexural capacity of the affected beams. The scope of the project includes investigating several methods of external post-tensioning using composite fiber wraps, permanent shoring, and eventual replacement of the beams. When the most feasible method is selected, contracting options will be explored to perform the repairs.

In closing, it is important to note that this seemingly simple transformation of simple-span prestressed girders to continuous spans should be attempted with caution, and significant attention must be paid during analysis and design to include loading conditions that can cause counterintuitive behavior such as secondary positive moments at the piers. More importantly, positive moment reinforcement should be designed and detailed such that any cracking, if it occurs, should be limited to the relatively less critical diaphragm region of this type of structural system.

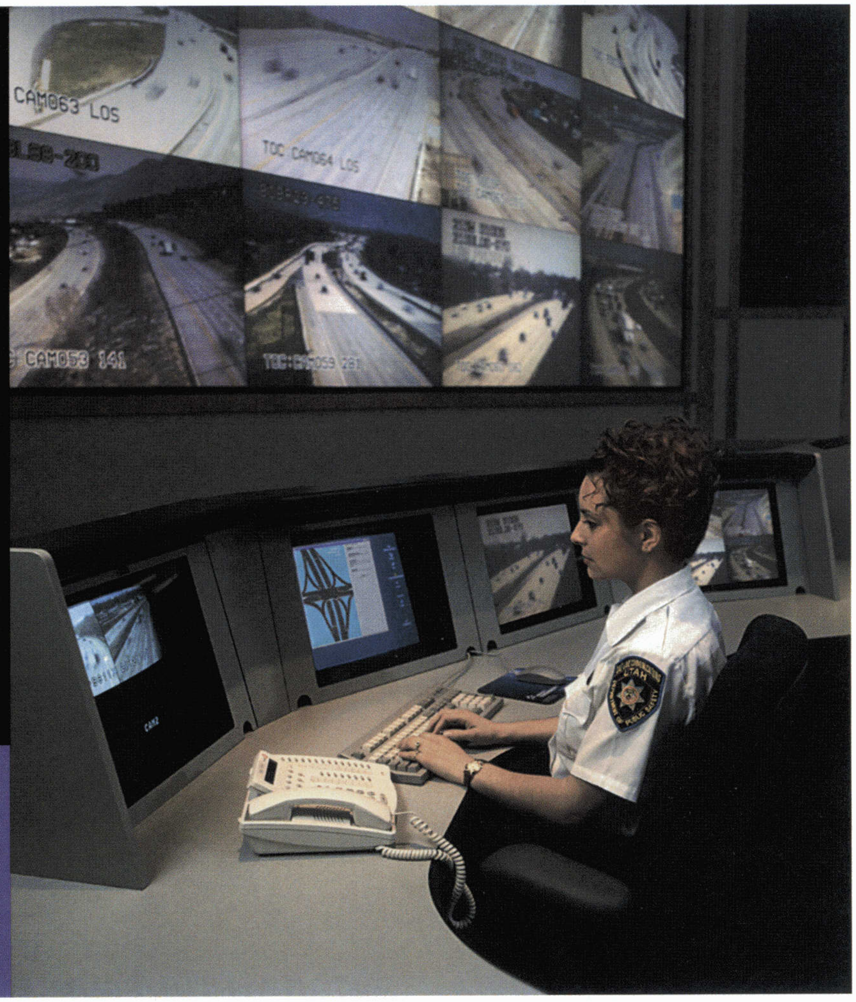
Niket M. Telang, P.E., is a senior engineer with Construction Technology Laboratories, Inc., and was the project manager for the Case Bridge evaluation. He has more than 10 years experience in bridge engineering and has managed several projects in bridge research, inspection, rating, rehabilitation, and design. He is currently the principal investigator for NCHRP Project 10-64, Field Inspection of In-Service FRP Bridge Decks, and managed NCHRP Project 10-43, Movable Bridge Inspection, Evaluation, and Maintenance Manual, in the past. Telang received his B.S. and M.S. degrees in civil engineering from Victoria Jubilee Technical Institute (University of Bombay) and Virginia Polytechnic Institute and State University, respectively.

Armin Mehrabi, Ph.D., P.E., is a senior principal engineer with Construction Technology Laboratories, Inc., and was actively involved in the Case Bridge evaluation. He leads the company's long-span bridge engineering activities, with a focus on the use of innovative techniques for bridge evaluation and inspection. In 1997, Mehrabi was chosen as one of *Engineering News-Record* magazine's Top 25 Newsmakers for his contribution to the development of nondestructive techniques for evaluation of cable-stayed bridges. He received his master's degree and doctorate in civil engineering from the University of Tehran and the University of Colorado at Boulder, respectively.

CAD and ITS Working in Concert

by K. Craig Allred

Field tests are integrating advanced traffic management systems with computer-aided dispatch systems to provide real-time information that can improve public safety.



The computer-aided dispatch (CAD) systems used by law enforcement and other emergency response agencies provide dispatchers and response units with real-time information on road incidents. These public safety systems typically track data on assignments to response units, locations of crashes, equipment locations and statuses, utility locations, and special hazards. If CAD systems and Intelligent Transportation Systems (ITS) could work together, public safety agencies would have instant access to real-time information on traffic and road conditions. Emergency responders would reach incident scenes more quickly and manage the responses more efficiently. By the same token, transportation agencies could use real-time information from CAD systems to manage the traffic-related effects of emergencies more efficiently.

Most existing CAD systems are proprietary, however, and are not designed to exchange information with CAD systems offered by other vendors, let alone with ITS technologies. Variations in formats and protocols for data exchange and messaging pose additional challenges, as do different system standards in the transportation and public safety communities.

To address these challenges, the U.S. Department of Transportation (USDOT) recently launched two projects to demonstrate that the technical and institutional barriers to

(Above) A staff member with the Utah Department of Public Safety operates the advanced traffic management system. *Photo: Derek Smith.*

The Traffic Operations Center at the Utah Department of Transportation.

Derek Smith

Scott Holmes, JRCA Design

The Valley Emergency Communications Center in Salt Lake County, UT.

integration of public safety and transportation systems can be overcome. The USDOT ITS Public Safety Program funded the two new field operational tests—one in Salt Lake City, UT, and one in Seattle, WA—to establish the feasibility and benefits of integrating public safety CAD systems with the advanced traffic management systems (ATMS) already used by transportation agencies as part of their ITS deployments.

The timing could not be better, since many State and local public safety agencies are planning long-needed upgrades for their CAD systems in anticipation of funding for homeland security.

"We are delighted to have the opportunity to work on a project of such national significance," says Richard Manser, interim ITS director with the Utah Department of Transportation (UDOT). "These technologies have the potential to improve public safety and security significantly through real-time sharing of incident-related information between public safety and transportation agencies."

Utah's Advanced Traffic Management System

In Utah, the State transportation agency already had integrated its CommuterLink advanced traffic management system with the Utah Department of Public Safety's CAD system in a test mode. The State will use USDOT funding to expand this integration to include several other CAD systems in the Salt Lake Valley. The major aim of the Utah project is to define and develop a common message set that can be easily integrated by CAD vendors without affecting their proprietary products or other sensitive information.

This level of integration will require an unprecedented degree of collaboration among several independent CAD vendors. The project also will mark the first time that integration and electronic transfer of data have linked such a wide variety of emergency management centers with a statewide traffic management center.

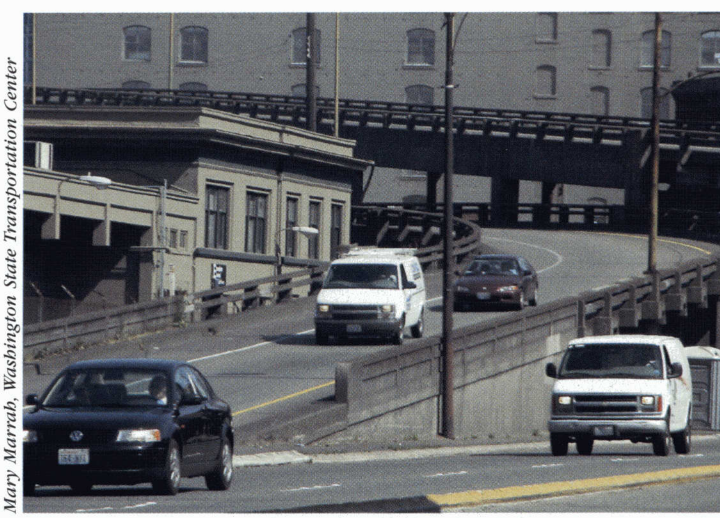
"UDOT and the Utah Department of Public Safety have been working across organizational boundaries for years and are setting a great example of partnering," says John Njord, UDOT's executive director. "This contract will allow us to take our past experience, build upon it, and share the results with the rest of the country."

Utah Integrates Four CAD Platforms

Utah will build on the solid, existing institutional relationships among public safety and transportation agencies in the Salt Lake City region to share a wide range of technologies for emergency response and traffic management. In addition to UDOT and the Utah Department of Public Safety, partners in the Utah project include the Valley Emergency Communications Center in Salt Lake County, the Salt Lake City Fire Department, the Salt Lake City Police Department, the Utah Transit Authority, four CAD vendors that provided the legacy systems used by the project partners, and TransCore—the UDOT contractor for systems management and integration.

Utah's CAD/ITS system includes four major components. The first is *enhanced message/data set functionality*. The originating agency will be able to select which agencies receive shared data messages. Agencies will be able to update or create incident records automatically using the shared data. Development of the message sets will be based on the most recent Institute of Electrical and Electronics Engineers' (IEEE) 1512 standards. Other transportation and public safety agencies around the country may want to use these systems at some point. For this reason, the message sets will be designed with open architecture that will allow for easy interface with other proprietary systems.

The second major component is *automated vehicle location integration*. The integrated CAD/ITS system will provide several tools to help the partners improve their daily operation. Automated vehicle location enables transportation and public



Mary Marrab, Washington State Transportation Center

Traffic exits SR99 in downtown Seattle, WA.

USDOT and DOJ Joint Initiative

USDOT is coordinating with the U.S. Department of Justice (DOJ), which has several programs related to cross-agency and cross-jurisdictional integration of CAD and records management systems (RMS). The goal is to facilitate the cross-agency and cross-jurisdictional integration of ITS, CAD, and RMS systems.

- *DOJ Office of Justice Programs Justice Extensible Markup Language Initiative.* This data-sharing initiative explores information sharing and technology integration in the justice and public safety communities. USDOT is working with the Department of Justice to coordinate with ongoing extensible markup language activities in the transportation community. For more information on this initiative, go to *http://it.ojp.gov.*
- *Interoperability Strategies for Public Safety (AGILE).* Sponsored by DOJ's National Institute of Justice, AGILE's mission is "to assist State and local law enforcement agencies to effectively and efficiently communicate with one another across agency and jurisdictional boundaries." For more information, visit *www.agileprogram.org.*
- *National Institute of Justice Communications Interoperability and Information Sharing Publications.* The National Institute of Justice publishes and identifies research reports, research summaries, guides, and other documents for practitioners, policymakers, and researchers interested in communications interoperability and information sharing. For more information, visit *http://ojp.usdoj.gov/nij/sciencetech/ciis_pub.htm.*

safety agencies to track the locations of their response units. Integrating and sharing automated vehicle location data will provide benefits to dispatch agencies, such as being able to convey the locations of snowplows to all field units concerned with roadway conditions.

Coupled closely with automatic vehicle location, *geographic information system capability* will provide dispatching agencies with real-time information for route guidance, estimation of arrivals, and identification of the response units closest to the location in need. Transportation operations managers can use the same information for incident tracking and managing incident severities.

The final major component is *CAD-to-CAD* and *CAD-to-ATMS infrastructure.* Upon completion of the Utah field operational tests, dispatchers and UDOT operations personnel will be able to send messages and incident status updates to one another with a simple click of the mouse. This automatic and seamless operation will eliminate the need to reenter data. All users will have access to more incident information and will be able to retrieve it more quickly. In the emergency management world, this access translates to saved lives, time, and money, and reduced traffic delay.

WSDOT

A traffic operations specialist monitors traffic in the Seattle Traffic System Management Center.

Washington Explores CAD Integration

The Washington State Patrol's upgraded CAD system, scheduled for initial installation in July 2003, will be integrated with the Washington State Department of Transportation's (WSDOT) Internet-based secure data network. The WSDOT network enables State, regional, and local agencies to share information about road incidents, weather conditions, traffic delays, and other situations. A key goal is to demonstrate how open communication between the law enforcement and transportation agencies can improve emergency response and dissemination of traveler information without placing additional burdens on the already-busy emergency response and radio dispatch staffs.

"This is a great opportunity for the [State] Department of Transportation and Washington State Patrol to work together to improve roadway condition reports for the traveling public," says Washington State Transportation Secretary Doug MacDonald. "Consistent and timely information delivered through our traveler information systems will help save lives and make the most efficient use of our highways."

Washington System Is Internet-Based

State patrol dispatchers throughout Washington State will share a common platform for the first time when the Washington State Patrol's upgraded CAD system goes online. The newly procured CAD system, which will output information using a universal data transfer capability, will be pilot-tested in one region before going statewide.

The Condition Acquisition and Reporting System (CARS) is an Internet-based system that enables State, local, and regional agencies to collect and share information on road incidents, weather conditions, traffic delays, and other situations. The acquisition and reporting system is based on ITS standards and exchanges data using Extensible Markup Language (or XML). Data from the acquisition and reporting system are used to coordinate roadway response; they also supply a portion of the traveler information content in WSDOT's 511 travel information system and Internet pages. Created by CastleRock Consultants, a partner in the USDOT project, the acquisition and reporting system is used as the basis for reporting 511 travel information by eight States in addition to Washington.

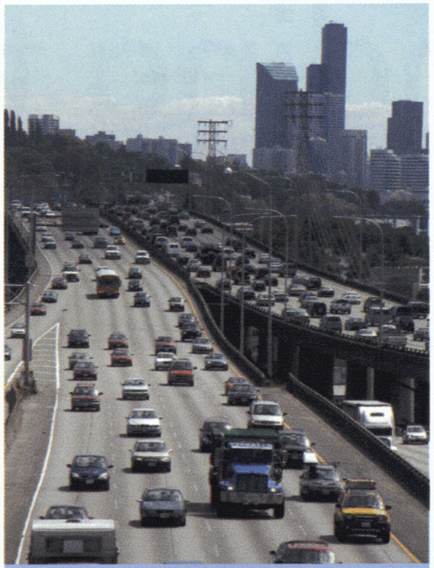
WSDOT plans to integrate CARS with the State patrol's CAD system by creating new systems-integration software with three components. The first component, *Primary Alert*, is a computer-based interface from the Washington State Patrol to WSDOT. The direct line ensures that a filtered report will appear in the WSDOT CARS within a minute of a transfer from the CAD system. The report will include onscreen map displays of the incident. The filters will ensure that the law enforcement agency releases only necessary and appropriate information to the transportation agency to address privacy and security concerns.

Response Support is the second component of the software. The information provided will help Washington State Patrol dispatchers ensure the most efficient response to the incident location. On a separate Web page that is linked to the State patrol's CAD system, troopers can find information about traffic, construction, or adverse weather conditions that could affect their response.

The final component, *Secondary Alert,* is a direct computer-based interface to secondary responders. Secondary Alert will reach, among others, emergency medical services, towing and recovery service providers, and utility companies. Secondary Alert will transfer incident information to responders about events in the State patrol CAD system and the WSDOT CARS. The Skagit County emergency medical service is partnering with WSDOT and the Washington State Patrol in the USDOT project. Towing and recovery services already are integrated into incident-response operations through a three-party agreement with WSDOT and the Washington State Patrol.

USDOT Supports Other Integration Efforts

In addition to the CAD/ITS field operational tests, the USDOT ITS Public Safety Program is supporting several other activities to promote the integration of ITS with public safety CAD systems.



Early-morning rush hour traffic on Interstate 5 looking south toward downtown Seattle from the overpass on NE 45th Street.

Mary Marrah, Washington State Transportation Center

- *IEEE Standard 1512,* Standard for Common Incident Management Message Sets for Use by Emergency Management Centers, provides a common set of automated messaging standards for exchanging vital data concisely, unambiguously, and rapidly. The standard addresses messages related to an emergency incident that are shared among the communications centers of various agencies. The standard is carefully tailored to allow a wide range of local variation in implementation, consistent with the National Intelligent Transportation System Architecture. For more information, visit www.its-standards.net/Documents/FSP1512_r2.pdf.
- *National Transportation Communications for ITS Protocol (NTCIP™).* NTCIP is a standardization project funded by FHWA and involving several standards-setting organizations. The project enables electronic traffic-control equipment developed by different manufacturers to operate with one another as a system to reduce the need for reliance on specific equipment vendors and customized one-of-a-kind software. For more information, visit www.ntcip.org.
- *National Fire Protection Agency (NFPA) 1221 Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems (NFPA 1221).* As a result of USDOT involvement in the ongoing development of this standard, a requirement has been added to the 2002 edition of NFPA 1221 to support automated information exchange between public safety and transportation information systems. The 2002 edition also provides updated information on call-taking and processing, and outlines requirements for portable and mobile radio capabilities. For more information, visit www.nfpa.org/catalog/product.asp?pid=122102&scr=nfpa&cookie%5Ftest=1.
- *Society of Automotive Engineers (SAE) Advanced Traveler Information System (ATIS) Standard J2354.* Completed activities include developing XML versions of the standards; building a demonstration model of a multistate, multimodal traveler information system that gathers information from several sources and then provides the information to the public and other agencies in a common, consistent format; and providing information about Federal travel information standards to State and local agencies. For more information, visit www.sae.org.

The more that Federal, State, and local agencies can learn from these projects—even those with older systems—the more quickly barriers to integration will fall. As integration becomes more widespread, the public's health and safety will have one more vital safeguard.

K. Craig Allred is the ITS public safety program coordinator in the USDOT ITS Joint Program Office of the Federal Highway Administration (FHWA) in Washington, DC.

For more information on the integration of CAD and ITS, visit www.itspublicsafety.net.

Responding to an Earthquake

by Shannon McCarthy

Alaska's transportation agency shares some lessons learned about emergency response.

Tremors hit. They strike during different days of the week and different times, summer or winter, and range from a mild shake to a true world-class disaster. Despite occasional shakes, or perhaps because of them, few people are prepared to make the transition from the normal activities of their daily work lives to responding to an earthquake disaster. But emergency plans and preparedness help States, communities, and individuals make that transition more quickly, with the right tools to get the job done.

(Above) Workers survey damage caused by Alaska's November 3, 2002, earthquake on the Denali Fault, which runs underneath one of the State's main roads, the Richardson Highway.

At 1:13 p.m. on Sunday, November 3, 2002, Alaska's interior shook from the State's largest earthquake in more than 30 years. At 7.9 on the Richter magnitude scale, the Denali Fault Earthquake reverberated throughout Alaska and continued releasing energy far to the southeast of its epicenter. Shocks were felt as far away as Pennsylvania and Louisiana.

Although measurable earthquakes occur in Alaska every day, officials at the Department of Transportation and Public Facilities (DOT&PF) immediately recognized that this quake was significant. They stepped into emergency response rapidly and effectively. Still, the Denali Fault Earthquake taught management and operators alike what it is like to respond to a large-scale disaster—and how to improve the planning and preparedness processes.

Alaska DOT&PF operates under two emergency plans. One is the Alaska Emergency Operations Plan, which outlines the actions that the State, local communities, and the private sector should take in the event of a disaster. The other is the State's Emergency Highway Traffic Regulation, updated in 1998, which outlines procedures for coordinating major military deployments with civilian traffic management in the event of a national emergency.

Within days after the Denali Fault Earthquake, Alaska DOT&PF moved from response to recovery. Design engineers, construction experts, and private sector contractors joined maintenance and operations personnel.

"This transition was crucial and yet the most difficult in the emergency response because it involved

All photos by Alaska DOT&PF.

multiple organizations and the coordination of resources," says Northern Region Director Andrew Niemiec. He adds, "We had a lot of experience under our belts, but some we had to gain on the job."

The Events of Sunday, November 3

Within an hour after the earthquake occurred, a small group of Alaska DOT&PF staff, including the director of the Maintenance and Operations Division, the public information officer, and area managers, gathered at the regional headquarters in Fairbanks, AK. The group began the process of assessing the damage and reporting what they knew to Alaska State Troopers, the media, and the public. Together, they acted as the DOT&PF Emergency Operations Center.

Meanwhile, Alaska DOT&PF's maintenance managers and foremen, stationed in remote locations throughout the interior, began implementing emergency procedures. Station foreman performed Level I inspections and reported their findings to the Fairbanks office. A Level I inspection consists of a visual check of roads, bridges, and airports, looking for any signs of deformation or obstruction, such as settlement, crevices, cracks, or slides.

Keeping America Moving during Emergencies and National Security Events

When disaster strikes, America's transportation system is its lifeline. The transportation system conveys those at risk away from danger and provides access for emergency response units. Yet in many localities, emergency preparations do not include plans for optimizing the operation and coordination of the transportation system during natural disasters or national security events.

For those States or localities that need to strengthen their transportation preparedness, the U.S. Department of Transportation (USDOT) can help. Through the new Public Safety and Security Program in the FHWA Office of Operations, USDOT offers tools and techniques to help surface transportation agencies prepare for and manage the recovery from natural and manmade disasters.

For more information, see the Public Safety and Security Program's Web pages at http://ops.fhwa.dot.gov/OpsSecurity/index.htm or contact Public Safety and Security Team Leader Vince Pearce, vince.pearce@fhwa.dot.gov.

The maintenance crews literally responded within minutes—identifying highway, airport, and bridge damage and, in many cases, performing temporary repairs on the spot. The Alaska DOT&PF attributes the rapid response to the decentralized nature of its regional organization. Station foremen were able to complete this task within 24 hours of the earthquake, driving hundreds of miles over four of Alaska's most important roadways.

This piece of asphalt buckled on a cracked section of the Tok Cutoff Highway, a major Alaska road.

The initial inspections revealed that the earthquake damaged eight of Alaska's roads, including four of the State's major highways. They included the connectors between Alaska's two largest cities, Anchorage and Fairbanks, and the only route leading out of the State to Canada and the lower 48. Two of the highways—the George Parks and the Alaska Highway—sustained limited damage. But two other major roads—the Richardson Highway and the Tok Cutoff—were impassable for many miles.

Reopening the Richardson

The Richardson, Alaska's first highway, stretches 589 kilometers (366 miles) from Valdez to Fairbanks. Well-traveled, the highway is a particularly critical road to the Alyeska Pipeline Service Company, owners and operators of the Trans Alaska Pipeline, since the pipeline follows the route for most of its length. The Denali Fault crosses underneath the Richardson Highway to the east of the earthquake epicenter. The quake damaged more than 32 kilometers (20 miles) of the roadbed.

Alyeska shut down the pipeline as a precautionary measure. The earthquake shifted the road sideways by 2.4 meters (8 feet) at the fault line, caused rockfalls along extended sections, and left cracks up to 1.5 meters (5 feet) wide across both lanes and as deep as 2.4 meters (8 feet). Alaska DOT&PF closed the road and began temporary repairs within the hour.

Staff members from Alaska DOT&PF examine a collapsed section of the Tok Cutoff Highway.

Working into Sunday night, Alaska's maintenance crews cleared the road of debris, removed broken asphalt, and filled in cracks. This quick action by Alaska DOT&PF enabled Alyeska to enter the area to check the pipeline and bring in equipment to repair structural damage. The oil that flows through this pipeline for the Port of Valdez delivers 17 percent of the Nation's domestic oil supply.

"Our ability to reopen the road was critical to Alyeska's emergency response," says Niemiec. "Shortly after midnight, we were able to reestablish a driveable surface and reopen the Richardson Highway. Alyeska could get through with their heavy equipment, and commercial vehicles and civilian traffic could get going again."

The Tok Cutoff

To the southeast of the epicenter, the Denali fault also runs under the Tok Cutoff Highway. The Tok Cutoff serves as a direct route for Anchorage and Valdez traffic accessing the Alaska Highway and is a heavily used commercial route. Damage was severe and extended for more than 81 kilometers (50 miles). The road dropped 1.8 meters (6 feet), literally collapsing extensive sections. Large cracks, ranging from inches to several feet wide and up to 3.7 meters (12 feet) deep, shattered the paved surface for miles. There was a lateral shift of 7 meters (22 feet) at the fault.

The rural communities of Mentasta, Northway, Tetlin, and Slana sustained heavy property damage. Mentasta Lake Road and Northway Road were impassable. The communities were cut off, without phones and road access, including access for emergency vehicles.

Again, the decentralized nature of the Alaska DOT&PF regional structure and delegation of authority worked well. The agency's crews were on the scene immediately. In fact, a plow truck from DOT&PF maintenance was actually on the scene when the shaking began. Slana Station Foreman Ernie Charlie radioed back to Slana for assistance and immediately organized the response in the Tok Cutoff area. He created a pioneer trail to Mentasta through the damaged sections, providing emergency access to the community.

The Alaska Highway

Maintenance crews in the area also discovered that the Northway Airport, located several miles off the Alaska Highway, was significantly damaged. The airport serves as an important customs entry for light aircraft from Canada. According to U.S. Customs, approximately 700 airplanes land at the airport each year. The earthquake created crevices over the entire 1,556-meter (5,100-foot) paved surface, a 203-millimeter (8-inch) drop along the centerline, and 0.3-meter (1-foot) heaves along the length of the runway. Foreman Gary Thomas officially closed the Northway Airport after seeing the extensive damage.

Back in Fairbanks

Back at the Emergency Operations Center, Jim Little, former maintenance director, was receiving and documenting damage reports and shifting resources to the hardest-hit areas. He was in close contact with the troopers and kept the Alyeska crews informed.

Based on these reports from the field, the public information officer began preparing a situation report and answering phone calls from the media and the public, both from Alaska and beyond. The public information officer position was a new one for the Alaska DOT&PF's Northern Region, with a staff member hired less than 2 months earlier. Having an information officer on staff relieved the maintenance director and staff members from a barrage of media requests, allowing them to focus on the task at hand—stabilizing the damaged areas.

The Days Following The Quake

Twenty-four hours after the earthquake, members of the DOT&PF Bridge Design Section began a Level II inspection, or an engineering analysis of the structures in the earthquake zone, including several bridges not owned by the State.

"Sticking to the strict lines of ownership was not advantageous to anyone," says Richard Pratt, chief bridge engineer. "We inspected any structure in the earthquake zone. Our most important job was to stabilize the situation and give those directly affected as much peace of mind as possible."

Flying up from Alaska's capital city of Juneau, members of the Bridge Design Section began inspecting more than 200 bridges in the earthquake zone on November 4—the day after the quake. In less than 48 hours, they completed the Level

Cracks and heaves on the runway were severe enough to close the Northway Airport.

II inspections and confirmed that several bridges were damaged.

Pratt adds, "Everywhere the bridge engineers went, they saw footprints in the snow, confirming that maintenance crews had been there the day before. Not a bridge was missed by either of the teams."

In fact, six interior bridges sustained damage. The bridge engineers recommended replacement of two spans located on the Tok Cutoff to restore structural integrity to the crossings. The bridge abutment walls had moved about 254 millimeters (10 inches) from the pressure of liquefied soil flowing toward the creek water. Although these bridges are still able to accommodate highway traffic legally, the soil movement put stress on the superstructure and left the bridges vulnerable to future earthquakes.

The DOT&PF engineers also detected shifting on the Tanana River Bridge, located at mile 1,303 on the Alaska Highway. An independent consulting firm confirmed that a span weighing more than 0.5 million kilograms (1.1 million pounds) shifted off its steel supports by nearly 102 millimeters (4 inches). The Tanana River Bridge, located about 18 kilometers (11 miles) south of Tok, was built in 1943 during the construction of the Alaska Highway. Restoration will include moving the superstructure back to its original position, installing lateral restraints, and repairing expansion joints.

In the days following the event, the DOT&PF construction employees oversaw the temporary repairs. Time was of the essence. The area had not yet received significant amounts of snow, and the temperatures remained relatively mild for an Alaskan winter. Maintenance crews needed the highways and airport restored to a condition that they would be able to maintain before the area received normal snow levels and a deeper freeze.

The DOT&PF Construction Division moved quickly and employed emergency procurement procedures to bring in contractors. Temporary repairs and reconstruction on the airport were completed 3 weeks after the initial damage, and the airport reopened to general aviation.

Temporary repairs also started on the Tok Cutoff, where damage was extensive. This reconstruction was particularly difficult, as the area continued to experience strong aftershocks in the month following the initial quake. The aftershocks prevented the soils from stabilizing. Temperatures were well below freezing, reaching as low as minus 29 degrees Celsius (minus 20 degrees Fahrenheit).

The Northway Road project was next and was completed at record pace. The DOT&PF contractors

This aerial shot shows extensive crevices along the Tok Cutoff Highway. During the first 48 hours after the earthquake, workers trucked in gravel to fill the cracks in the roadway.

worked through the Thanksgiving weekend, and on the Tok Cutoff through the Christmas season, until the work was completed.

In the days following the earthquake, the process of documenting the damage began. Alaska DOT&PF staff worked with Karen Schmidt, assistant division administrator for the Federal Highway Administration (FHWA), to survey the damage. The work was especially difficult because of the large geographic area they had to cover in a short time.

The State also assigned staff to serve as the single point of contact for the Federal Emergency Management Agency (FEMA) and FHWA for emergency response-related repairs.

Incident Command System

The DOT&PF emergency response closely followed the Incident Command System (ICS), with the foremen functioning as onsite incident commanders. ICS is a nationally recognized method of emergency response that enables multiple organizations to provide assistance in an emergency or national disaster under a common command and control system. Alaska DOT&PF responds to emergencies year-round, including blizzards, avalanches, freezing rain, or flooding. The management structure is designed to empower onscene personnel to make decisions to get the roads open and keep the public safe.

Few Northern Region employees were actually trained in the ICS. Although the move from stabilization to recovery was relatively smooth, Alaska DOT&PF staff members were learning on the job. Several months after the earthquake, the staff took formal ICS training to prepare for the next disaster.

Preparing for Future Emergencies

Alaska was fortunate in several ways. The Denali Fault earthquake affected rural areas with small, spreadout communities. Although those communities sustained serious property damage, only one injury occurred (a woman evacuating her home). No tall buildings and no overpasses or tunnels were involved. If the earthquake had occurred closer to Fairbanks or Anchorage, the story might have been different.

Even so, the quake served as a test case for preparedness and recovery. First, the large size of the geographic region where the damage occurred is helping scientists analyze how earthquakes travel—and where structural damage can be expected. Second, the Denali Fault earthquake is serving as a test case for transportation agencies in how to respond to road and bridge damage that occurs hundreds and hundreds of miles apart.

In addition, Alaska DOT&PF learned about completing emergency repairs in winter and the problems that can appear the following spring. In this case, the November earthquake raised the water levels in the underlying soils, which subsequently refroze. (Typically during a winter freeze, the water levels drop significantly; however, with the earthquake, the water levels rose and then froze at higher levels than normal.) Spring brought a wet breakup—and soft roads that needed another round of repairs.

Alaska DOT&PF also learned lessons about disaster recovery, especially the documentation of damage for cost-recovery purposes. In a few instances, the effectiveness of the maintenance crews outpaced the agency's ability to photograph and record the damage. Although DOT&PF was able to go back to those repairs and identify the damage, more widespread damage in an urban setting could pose greater difficulties.

Finally, Alaska DOT&PF Northern Region will continue ICS training and make the training more widely available. Although the response largely resembled the ICS structure, the training will establish improved communication and partnerships with the State and Federal emergency response agencies. Dedication, care, concern, and cooperation led to Alaska's success in responding to this earthquake. However, the DOT&PF has not taken the lessons learned in this situation for granted. The earthquake represented a benchmark—a time when everyone in the State of Alaska was reminded that true disasters can strike at any time without warning. Alaska currently is fine-tuning its response system and preparing a formal written plan to save lives, minimize damages, and reduce the risks.

This aerial view shows the damage to a bridge on the Tok Cutoff.

Shannon McCarthy is a public information officer for the Alaska DOT&PF. She has worked with the media for more than 15 years since earning her B.A. from the University of Alaska Fairbanks.

A Fix for Aluminum Overheads

by Paul Mooney

Using innovative fiber-reinforced polymer repairs to correct distress in welded joints on aluminum sign structure trusses.

In the early 1960s, State departments of transportation (DOTs) began using aluminum trichord overhead structures to support signs along our Nation's highways. The advantages of using aluminum were obvious. It is lightweight, costs less than steel, and is inherently resistant to rusting. In 1994, however, the American Association of State Highway and Transportation Officials (AASHTO) started to include fatigue as a design factor for overhead signs.

"This development, combined with observations of cracking and occasional structural failures in aluminum signs," says Chris Pantelides, professor of civil engineering at the University of Utah, "alerted engineers to a potential life-threatening problem that may exist in States throughout the country."

Over time, wind forces create stresses on an aluminum structure, eventually causing cracks to appear in the welded joints of the truss diagonals. If these cracks are not discovered and repaired, a welded joint eventually could fail and cause an aluminum diagonal to fall onto the roadway. "These problems are surfacing in large numbers now that many of these aluminum sign structures have been in service for 30 years or more," says Pantelides.

The consequences of a failed welded joint could be tragic, especially on high volume roads where traffic moves continuously and at high speeds beneath hundreds of aluminum overhead sign structures.

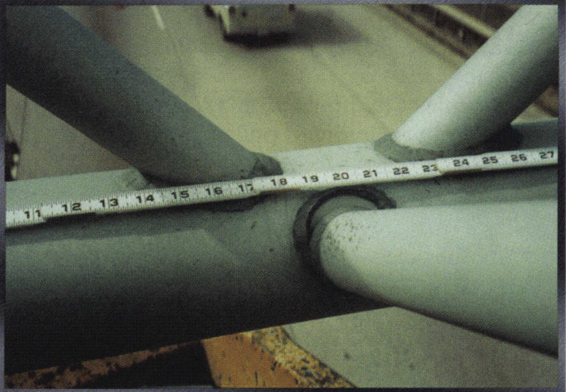
Fortunately, New York State DOT (NYSDOT) engineers, working with private industry and a research team from the University of Utah, found an inexpensive way to repair problematic structures to increase their safe and useful lives. Using a fiber-reinforced polymer (FRP) composite to wrap cracked joints, workers can restore the structural integrity of a cracked joint to virtually the same strength as the original aluminum weld. The cost of the material is minimal, and the repair can be conducted in the field. In sum, this solution can be applied with minimum difficulty.

A Sizable Problem

NYSDOT engineers first became aware of a problem when maintenance crews reported some minor failures of truss diagonals. Those small failures alerted the engineers to a potentially larger problem.

"It was decided to inspect all of the aluminum overhead signs on Long Island to determine the extent of the problem," says NYSDOT Senior Civil Engineer Harry White. "Initial inspections in one area of the State revealed that approximately 10 percent of all the overhead sign structures had some form of structural damage. We then decided to inventory and inspect every overhead sign structure in the State. If we hadn't inspected, the risk would still have been unknown. There are more than 2,000 of these types of structures in service in New York. Depending on the size and location, replacing an overhead sign structure can cost as little as $50,000 or up to $300,000 for a large structure carrying variable message signs."

With little warning and no time to prepare for sticker shock, NYSDOT suddenly was facing a potential $25 million problem.



After many years in service, aluminum trichord sign structures often develop significant cracks and even complete failures in their welded connections, as shown in this photo of a failing joint. Redundant connections in most cases prevent pieces of the structure from falling onto the highway, but signs with failing joints need to be repaired or replaced.

NYSDOT

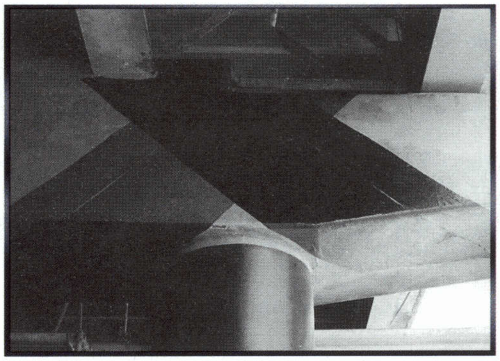
Finding a Low-Cost Answer

Facing the tremendous cost and logistics of replacing hundreds of overhead sign structures spanning some of the busiest roads in the State, the agency needed to find a better solution. At the time, John Neidhart was a senior civil engineer for NYSDOT and head of the overhead sign structure unit. Neidhart recalls, "We were thinking of all kinds of crazy repair ideas, and someone directed us to an FRP [fiber-reinforced polymer] contractor." At the time, these composites already were being used to retrofit substructures in New York.

Fiber-reinforced polymers have been used successfully in

Research on Fiber-Reinforced Plastic Composites

The American Society of Civil Engineers' *Journal of Composites for Construction* recognized the research by Professor Chris Pantelides and his former student Dr. Janos Gergely of the University of Utah as the "Best Paper for Applied Research" in 2002 for work on carbon fiber-reinforced plastic composites. The initial ankle-wrap design for the overhead aluminum trichord signs originated from this research.



A bridge column and bent cap is wrapped with carbon fiber-reinforced plastic composites for seismic protection. *Photo: Structures Research Laboratory, University of Utah.*

"The ankle-wrap technique using carbon fiber-reinforced plastic composites was designed to provide an alternative to steel plate connectors, which are susceptible to corrosion and difficult to implement," says Pantelides. "We were overseeing this technique being applied to the I–80 bridge over State Street in Salt Lake City when Larry Cercone of Air Logistics Corporation told me about the problems that New York was having with overhead aluminum trichord signs. He asked me if I wanted to look into whether this technique could be used to repair cracked welded connections, and I said yes."

However, wrapping aluminum joints presents new problems. "The key is to make sure you get good adhesion to the aluminum surface," says Pantelides. "With the proper preparation of the aluminum surface, we found we could obtain a strong bond."

Pantelides is planning on presenting the findings of his research for repairing aluminum overhead trichord signs at the 2004 Transportation Research Board annual meeting in Washington, DC, during the week of January 12.

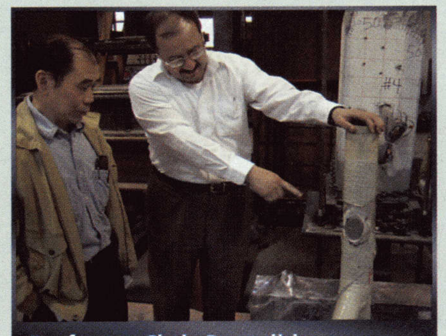
many transportation applications, but this was the first time they were considered as a wrap for welded aluminum joints on overhead signs. NYSDOT and the Utah DOT organized a pooled-fund study to determine whether fiber-reinforced polymers could be used to repair cracked aluminum joints. Larry Cercone, a consultant with Air Logistics Corporation, contacted Chris Pantelides to conduct the study.

Testing a Practical Solution

The research was designed to test cracked aluminum weld connections that were either unwrapped or wrapped with fiber-reinforced polymers. Researchers wanted to see whether the cracked aluminum welds could be replaced by this composite material. The research also tested aluminum chords that had not been previously welded but were reinforced with fiber-reinforced polymers. For these specimens, a tack weld (for alignment) was applied and then wrapped with the composite material.

Testing involved placing repetitive forces simulating wind on the test specimens. A triangular load frame was built to enable the diagonal of the specimen to be positioned vertically, directly under an actuator (a device that converts hydraulic energy into mechanical energy). The actuator applied loads on the joints of specimens at the same angles that natural forces act on the structure in the field.

The results were promising. Cracked samples repaired with fiber-reinforced polymers achieved strength in excess of 115 percent of the original welded connection. In addition, samples fitted only with a tack weld and fiber-reinforced polymers reached



Professor Chris Pantelides discusses study results with Utah DOT engineer Dan Hsiao at the University of Utah's research lab.

Paul Mooney

capacities virtually equivalent to a newly welded aluminum connection.

New York Implements The Solution

The New York transportation agency watched the test results closely and implemented the solutions as early as possible. Initial results enabled NYSDOT engineers to consider the repair method effective for 2 years.

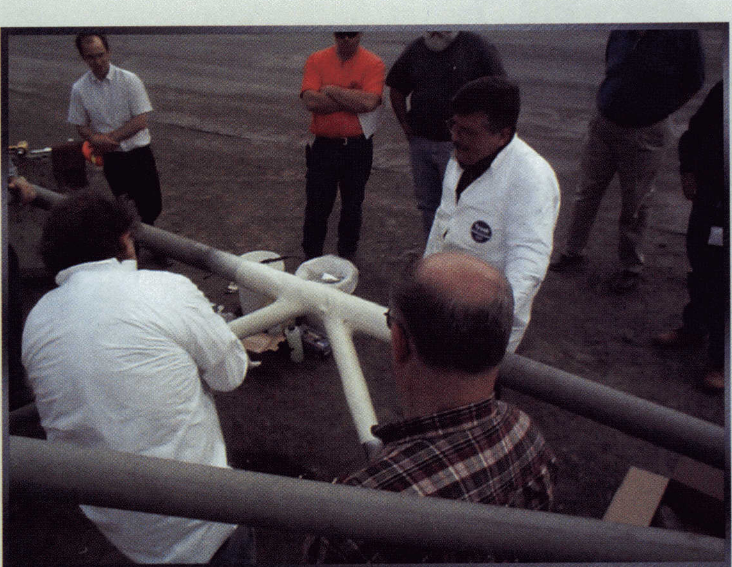
"Adding just 2 years of usable life to a structure is a tremendous benefit," says White. "It allows the OSS [overhead sign structure] fabricator to work the replacement structure into the schedule, rather than having to stop current production to fabricate an emergency replacement structure. Having the OSS fabricated and erected under an emergency situation significantly increases the cost over typical construction. This repair eliminates those extra costs."

As additional results continued to confirm the effectiveness of the repair technique, New York engineers upgraded their confidence in the repair. "Additional results from the study allowed us to consider the repair effective for 5 years," says White. As long as the technology proves to be successful over time, estimates of the lifespan of the repair will continue to increase. "Once the repair is complete, we consider the overhead sign structure to have its full load-carrying capacity," says White.

One of the most attractive features is that the repair can be made in place at a minimal cost and in about 3 hours' time (discounting time for traffic control). Once the necessary work zone is set up, trained maintenance or contractor workers can repair the structure on the roadway using a manlift.

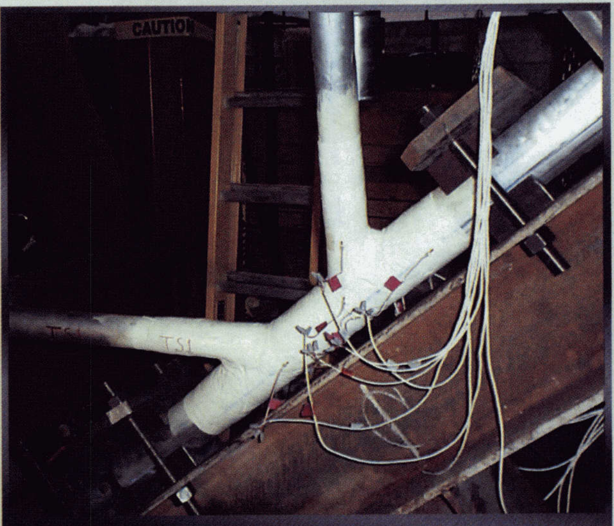
One of the keys to successful implementation is to make certain that the surface is clean prior to wrapping, ensuring proper adhesion to the aluminum surface. One approved system requires 37 simple steps to complete the repair. "The repair itself requires care and diligence by the workers, but it is not difficult," says White.

Larry Cercone says, "The application of the FRP-aluminum adhesion is based on standard aerospace procedures. First, absorbent pads are hung beneath the joint to capture



Engineers complete the final steps of a joint repair. Repairs such as this require attention and care, but generally are not difficult for work crews.

NYSDOT



Two welded aluminum joints fitted with strain gauges are tested for fatigue resistance and load-carrying capacity. Forces in the laboratory simulate thousands of high wind events.

Structures Research Laboratory, University of Utah

any chemicals used. The surface is prepared using an alkaline chemical, acid, and water to clean and etch the surface to improve the mechanical bonding properties of the aluminum. Primer and an adhesive are applied prior to the FRP. Four different weaves of FRP—a fine woven wrap, a heavier weave, a tubular braid, and unidirectional tendon wrap—are applied strategically on the joint to achieve the needed strength characteristics.

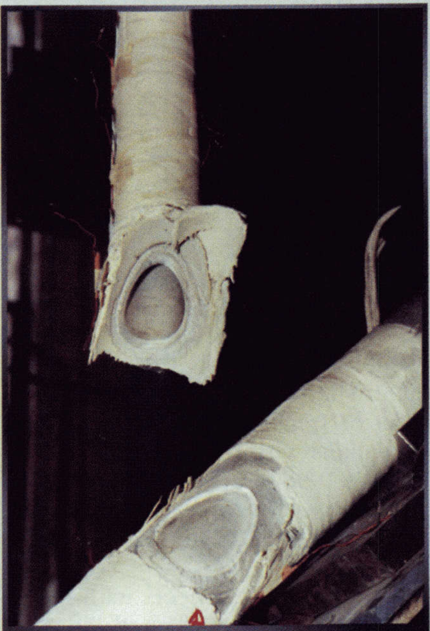
"Water acts as the catalyst to start the chemical reaction that hardens the material," Cercone continues. "The FRP achieves its strength approximately 60 to 90 minutes later. The only byproduct from the reaction is carbon dioxide, making the repair environmentally safe. Optionally, the cured FRP can be painted to match the rest of the aluminum structure so the repair will be invisible to the traveling public."

When a contractor repairs a sign structure, NYSDOT requires an inspector to be present, or the procedure is videotaped. The agency also requires all repaired structures to be inspected annually.

According to White, the cost of the repair is far less than that of replacing the structure. The repair materials include surface cleaning supplies, an epoxy for adhesion, the composite material, and a few other low-cost materials. In total, NYSDOT spends approximately $300 on the materials needed for each joint repair. Few tools are needed, aside from a cordless drill and scissors.

Looking toward the Future

New York engineers continue to inspect repaired structures and watch for additional results from the ongoing research. They are confident in the repairs as a temporary fix until the structures can be cycled into a replacement program. Future research and experience will determine whether the repair can be considered more permanent.



The original aluminum weld becomes exposed after a wrapped sample was pulled apart by a massive hydraulic-powered actuator. Results from the tests revealed that a cracked joint repaired with the fiber-reinforced polymer wrap was just as strong as a new welded joint.

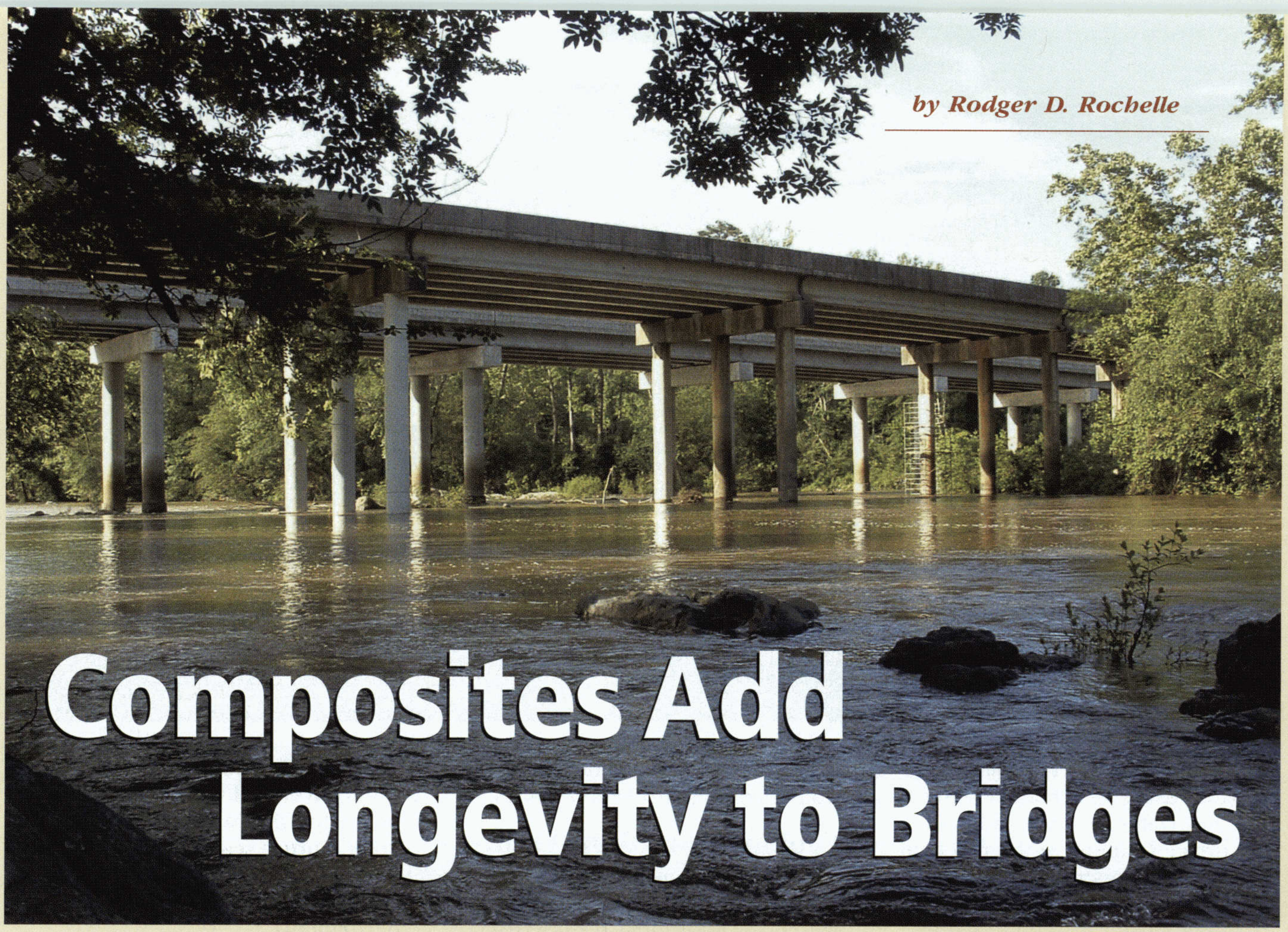
Structures Research Laboratory, University of Utah

The important thing is that the safety of the motoring public in New York is being held to the highest standard. State DOTs around the country strive to make highway facilities as safe as possible in light of limited budgets. This repair accomplishes both goals. It saves money, and, more importantly, it protects lives.

AASHTO's Technology Implementation Group (TIG) chose to support nine technologies that are likely to yield significant economic or qualitative benefits. The group added repairing hazardous sign structures to their technology priority list.

Paul Mooney is the technology and marketing specialist for the Federal Highway Administration's Utah Division Office.

For more information, contact Harry White II, P.E., senior civil engineer, NYSDOT, 518-485-1148; John Neidhart, P.E., senior civil engineer, NYSDOT, 518-485-5700; or Chris Pantelides, P.E., professor of civil engineering, University of Utah, 801-585-3991.



by Rodger D. Rochelle

Composites Add Longevity to Bridges

North Carolina uses fiber-reinforced polymers to rehabilitate bridges and extend their service lives.

The general need for bridge repairs across the Nation is widely reported. Whether subject to frequent application of road salt in the Northeast and Midwest or exposed to the naturally corrosive environment in the coastal States, bridges often suffer from severe chloride loading. Carbonation, sulfate attack, alkali-silica reactivity, and chloride reduce the lifespan of many structures. Statistics available through the Federal Highway Administration (FHWA) National Bridge Inventory indicate that many structures still are in need of repair.

North Carolina has the second largest State-maintained highway system in the United States, with more than 78,000 road miles, including 17,000 bridges. Despite the large inventory, the State's statistics for bridges over the last decade mimic the trend at the national level. Currently, about 30.7 percent of North Carolina bridges are considered deficient compared with 39.4 percent in 1992. The North Carolina Department of Transportation's (NCDOT) goal aligns with the one stated in FHWA's 1998 Strategic Plan, namely to decrease the percentage of deficient bridges to 25 percent by the year 2008.

Accordingly, engineers with the NCDOT Structure Design, Bridge Maintenance, Materials and Tests, and Research and Development units are collaborating to further reduce the bridge maintenance backlog. They are working on two fronts concurrently: durable design and innovative materials.

From a design perspective, durability is a given. North Carolina's structures are subject to a wide variety of chloride infiltration from applications of road salt in the Piedmont and Western regions to waterborne and airborne chlorides along the coast. Improvements in designing bridges for durability are therefore paramount to reducing the maintenance backlog.

For large structures over the coastal sounds or among the islands of the Outer Banks, where water chloride content can reach 17,000 parts per million, NCDOT engineers have used a mathematical model for systematically designing bridge components for a service life of 100 years. The concept is extrapolated to smaller bridges along the coast, by incorporating mineral and chemical admixtures, high-performance materials, and alternate concrete-reinforcing products.

From a bridge maintenance perspective, NCDOT is looking to innovative materials for bridge rehabilitation and extension of service life.

(Above) The eastern portion of dual bridges on U.S. 64 over the Haw River in Chatham County, NC. The bridge that was rehabilitated using composite fiber-reinforced polymer materials is shown in the foreground. *Photos: Advanced Structural Technologies.*

One of the fastest-growing exploration areas is the use of composite materials, specifically fiber-reinforced polymers (wrap).

Paul Simon, bridge engineer in FHWA's North Carolina Division Office, predicts that "composite bridge components are on the horizon of revolutionizing bridge materials. Within 10 years, the use of wrap products could be routine in bridge construction and reconstruction."

Chatham County Bridge

Bridge maintenance engineers often are confronted with rapidly deteriorating concrete caused by expansion of the corroding reinforcing steel and subsequent cracking and spalling (chipping away) of the overlying concrete cover. Exposed surface area increases the chloride ingress, which in turn, perpetuates and accelerates degradation. Such was the case with the westbound bridge on U.S. 64 over the Haw River in Chatham County, NC.

Built in 1982, this two-lane structure is approximately 214 meters (700 feet) long. Each of the bridge's ten supporting piers is roughly 9 meters (30 feet) tall and has three 0.9-meter (3-foot)-diameter columns on top of spread footings. But the similarities among the columns end there, as their condition varied widely when inspected in 2002.

Many exhibited no visible signs of degradation, and core samples revealed chloride content well below the commonly accepted corrosion threshold of 0.5 kilograms per cubic meter (1.5 pounds per cubic yard) of concrete. In contrast, several others showed excessive spalling and chloride content as high as 2.1 kg/m^3 (6 lbs/yd^3) at a depth of 50 to 75 millimeters (2 to 3 inches) below the surface of the column. Inconsistent and inadequate concrete cover contributed further to the variations in condition.

During the inspection in 2002, the aggregate rating of the columns was "fair." The maintenance personnel issued a Prompt Action Notice, however, to address several severely degraded columns. Overall, 15 columns required repairs. Since the deteriorated area represented only 30 percent of the total length of the columns, however, maintenance personnel sought rehabilitation rather than total replacement.

Moreover, NCDOT was intent on minimizing traffic disruptions on this newly widened four-lane facility. In response to these needs, NCDOT research personnel applied for a grant through FHWA's Innovative Bridge Research and Construction program. The grant application specifically requested $95,000 for this inaugural use of fiber-reinforced polymers in the NCDOT bridge program. Upon obligation of the FHWA funds, NCDOT selected an advanced composite system of fiber-reinforced wraps. An engineer with Fyfe Co. LLC, of San Diego, CA, Sarah Witt, recommended "unidirectional glass fibers embedded in 100 percent epoxy matrix to provide additional confinement to the existing bridge columns." She added, "The application will take advantage of the system's very high strength-to-weight ratio relative to more traditional repair techniques."

Specifically, NCDOT chose a glass fiber product and two epoxies to saturate the fabric. The first epoxy was used for most of the project, while the second one treated the bases of three columns immersed in river water, to enable underwater curing of the wrap system. In the fall of 2002, representatives of the supplier and NCDOT's Bridge Maintenance and Research units met to define the project scope. They identified spalled or cracked concrete over a collective column length. Intact concrete extending 1 meter (3 feet) beyond each spall was earmarked for wrap to ensure that the degraded portion of the column was fully encapsulated. Four of the 15 columns warranted the glass wrap for their entire lengths.

By the late fall of 2002, the NCDOT Bridge Maintenance forces began the important work of preparing the columns. Inordinate rainfall and resulting fluctuations in the river's water level disrupted the preparatory operations. Debris common to the Haw River damaged scaffolding on more than one occasion, adding potential safety risk to the project staff.

Despite the environmental challenges, crews completed the preparations in less than 1 month. They carefully examined all spalled areas and removed surrounding concrete to an area and depth adequate to ensure that all remaining concrete was sound. Exposed reinforcing steel was wire-brushed by hand and painted with a moisture-cured urethane coating.

The entire area of the concrete spall was treated with three products. The concrete was primed with a two-part 100 percent epoxy

Advanced Structural Technologies

Working in the median strip adjacent to the bridge in Chatham County, these crew members are saturating the glass fiber-reinforced polymer fabric.

primer. The concrete spall then was filled with a combination of a 100 percent solids urethane epoxy modified polymer, a filler, to create a three-part patching material specifically suited for vertical surfaces. This combination provided a highly impermeable patch that was sufficiently malleable to fill small voids.

In mid-May of 2003, the certified contractor for the project began installing the fiber-reinforced polymer. After using a leveling adhesive to smooth large variations in the patch material surface, the contractor began to wrap each deteriorated column. For this process, the glass fiber fabric is cut to length and "wetted-out" using a machine specifically tailored to optimize saturation.

The crew then transported the fabric to the column via a boom truck and boat, and applied the fabric in a continuous nonspiral wrap. The precut length of each piece of fabric provided a two-layer wrap with a minimum overlap. During the 48-hour curing window, the crew applied a coat of gray paint directly to the glass wrap. The timing of the paint application enhanced the bond between the wrap and the paint. The gray color offered a reasonably close match to the surrounding concrete, making it blend better with surrounding materials.

The onsite inspections included a daily diary of activity and verification of resin mixes and mixing procedures, fabric saturation, and glass wrap and paint applications. In addition, the inspecting firm collected a minimum of two test panels from each day of production work. Two individual laboratories tested these witness panels in accordance with American Society for Testing and Materials (ATSM) D-3039 to determine the conformance of the glass wrap system and components to material specifications.

John Levar, president of the inspection firm, Advanced Structural Technologies, says that the inspector's role is not simply "to verify that the materials were fabricated and installed properly, but also to establish a baseline condition of the repair so that future NCDOT inspections will have adequate information to successfully evaluate the structure and the repair technique."

Although high water levels in the river delayed the underwater wrap

Advanced Structural Technologies

Workers apply two segments of glass fiber-reinforced polymer wrap to a column.

Advanced Structural Technologies

A worker applies gray paint to match the concrete of the column.

operations, almost the entire installation was completed within 2 weeks. A typical rehabilitation approach such as using shotcrete or concrete jackets would have required a much greater mobilization effort, far longer construction times, and probable lane closures.

Discussing his first experience with the glass fiber-reinforced polymer wrap, NCDOT Bridge Maintenance Supervisor Kevin Smith described the material as "impressive and certainly an easier solution than encasing the columns in concrete."

To replace this bridge would cost more than $2 million and take years to complete. The fiber-reinforced polymer wrap solution restored the columns' original strength at a price tag of approximately $120,000.

This project demonstrates the practicality of using fiber-reinforced polymers in bridge maintenance. At this site, composite materials provided an environmentally friendly, cost-effective, and rapid solution to a challenging maintenance issue. Perhaps most importantly, the fiber-reinforced polymer wraps were applied without lane closures and associated traffic delays. For these reasons, public interest in this rehabilitation project has been strong and favorable. The project was featured by local radio, three television stations, and two major newspapers.

"This project exemplifies the Department's commitment to improving efficiency," said NCDOT Transportation Secretary Lyndo Tippett. "Not only is the use of this material a major accomplishment for NCDOT, but also it is an advantage for the citizens of North Carolina. Savings like this allow us to apply more money toward other pressing maintenance projects in the State."

Mill Creek Bridge

Although the Chatham County site has become North Carolina's best-known use of composite materials, NCDOT recently placed in service a bridge deck made entirely of a glass fiber-reinforced polymer. Located roughly 16 kilometers (10 miles) northeast of Charlotte on S.R. 1627 over Mill Creek in Union County, the bridge incorporates a pultruded fiber-reinforced polymer deck. The bridge deck system enabled rapid replacement of the aging bridge superstructure.

The NCDOT team placed five individual glass fiber-reinforced polymer deck panels into position and made them composite with underlying steel stringers through in situ placement of shear studs and grout. State Bridge Design Engineer Greg Perfetti reflects that the glass fiber-reinforced polymer deck has "proven to be a viable, light-weight, corrosion-resistant alternative to a conven-

Advanced Structural Technologies

This view of the Chatham County bridge was taken when nearing completion of the fiber-reinforced polymer wrapping and painting stages. The completed work appears as lighter gray.

NCDOT

Crews place the glass fiber-reinforced polymer deck panel on a bridge over Mill Creek in Union County.

tional reinforced concrete deck, and the ease with which it can be placed fulfills the need for structural options that minimize the impact on the motoring public."

The bridge was subjected to multiple controlled load tests as part of an NCDOT-sponsored research project. The research out of the University of North Carolina at Charlotte employed roughly 80 gauges and instruments to collect data on deflections, distribution factors, strains, and levels of composite action. The research afforded NCDOT an opportunity to affirm the design protocol for a glass deck and to learn how it behaves as a part of a fully operational bridge.

Macon County Bridge

Another bridge, located in Macon County, NC, soon will include fiber-reinforced polymer materials. Construction of a new 49-meter (160-foot)-long bridge on S.R. 1470 over the Cartoogechaye Creek is expected to begin in early 2004 and will entail substituting fiber-reinforced polymer reinforcing for conventional mild steel reinforcing in both the concrete bridge deck and approach slabs. Additional research will be conducted on this bridge and the fiber-reinforced polymer components to validate the design procedures and assumptions made for the project.

A Bright Future

All three of these projects were funded in large part by FHWA's Innovative Bridge Research and Construction program. The total contribution allocated from this program reached $700,000 for these three projects alone. To date, NCDOT has received seven such grants totaling $2.3 million.

These fiber-reinforced polymer projects exemplify the objectives of the FHWA program. John Hooks, the FHWA program manager, emphasizes that the Innovative Bridge Research and Construction program "has spurred innovation by providing funds to offset the cost of demonstrating high-performance and innovative materials in 288 bridge projects across the Nation. Solutions developed and validated under [this program] will help engineers extend the life of existing bridges and build new bridges better."

This certainly has been the case in North Carolina, particularly in the exploration of further uses for fiber-reinforced polymer products. And the future for using composite materials by NCDOT is bright. State Bridge Maintenance Engineer Lin Wiggins foresees a "much wider use of composites in our maintenance activities . . . [They are] particularly useful in the repair of girders damaged by overheight vehicles."

In fact, fiber-reinforced polymer is increasingly being considered to correct construction deficiencies, rehabilitate difficult-to-replace substructure members, repair collision damage to existing structures, reduce life cycle costs, and minimize traffic delays. To support these endeavors, the NCDOT research program currently is facilitating a 2-year, $160,000 research project by North Carolina State University. Dr. Sami Rizkalla at the university summarizes the study as a "testing of damaged girders, including a variety of fiber-reinforced polymer strengthening techniques . . . resulting in design guidelines, selection criteria, and construction specifications" suitable for bridge design and maintenance practitioners.

Upon completion of this research project, expected in 2005, the findings will be distributed across the Nation.

The North Carolina Department of Transportation is committed to building safe, durable, cost-effective bridges. Exploiting cutting-edge technology, such as that offered by fiber-reinforced polymers, provides a potential avenue through which existing deficient bridges may be replaced with structures of significantly greater longevity.

Rodger D. Rochelle, P.E., is the State research engineer with NCDOT and manager of the NCDOT research program. He has a bachelor's degree in civil engineering and a master's degree in structural engineering, both from Duke University. He is a member of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee and the Transportation Research Board (TRB) Subcommittee on Bridge Aesthetics, an associate member to the National Science Foundation Industry/University, Cooperative Research Center for the Repair of Buildings and Bridges with Composites, and a certified public manager.

For additional information on the use of composites in North Carolina, please contact Rodger Rochelle at 919-715-4657 or rdrochelle @dot.state.nc.us.

The Public: Key to Successful Projects

by Alexandra Zetlin and Shane Ojar

Community involvement can be pivotal—witness the recent reconstruction of two New York City bridges.

How do you tell the people of a metropolis like New York City that they will spend an extra 15 minutes in traffic for the next 2 years just to travel across the Williamsburg Bridge? How do you break the news that for 30 months they will have no subway service across the north side of the Manhattan Bridge? An effective public involvement program is the key.

Over the past 20 years, something amazing has happened in the New York metropolitan area—and across the country. Stakeholders are being asked to become partners with government agencies in developing and conducting transportation projects. This level of public involvement was not always the case. Until the early 1970s, Federal, State, and municipal agencies planned roadway construction with little input from the communities affected by the work. But today all that has changed.

By involving stakeholders in the decisionmaking process, New York City has emerged as a national leader in conducting public involvement programs. The city plans and constructs transportation projects from start to finish with the public's input. The result? Everyone can live with and be proud of the roads in New York.

How does the outreach process really work? An effective public involvement program requires a strategic outreach plan and lots of teamwork. Before the program can begin, the outreach plan needs to include the following steps: identifying the target audience(s), determining what information is needed and when, and deciding on the communication methods that will be used to deliver the information.

In 2001, to rehabilitate the Williamsburg and Manhattan bridges, the New York City Department of Transportation (NYCDOT) fielded a team consisting of an engineering consultant and a communications firm. Together, the two companies were tasked with reconstructing the Williamsburg and Manhattan bridges, educating the public about how the project would affect them, and addressing stakeholders' concerns.

Getting the Word Out

In the New York metropolitan area, as in most parts of the country, the word "construction" has some negative connotations with commuters and other motorists, residents, and merchants who may envision detours and traffic congestion. Stakeholders may be pessimistic about construction projects, fearing that the work might go over budget, finish late, and disrupt their lives. Due to the city's population density, reconstruction of existing facilities such as roadways and bridges cannot be done without disturbing the surrounding communities or interrupting the flow of traffic or the movement of subway trains. The challenge was to reconstruct

(Above) A view of the Williamsburg Bridge from Brooklyn.

All photos by Shane Ojar.

both the Williamsburg and Manhattan bridges with minimal impact on the public.

The most difficult challenge was maintaining traffic during the reconstruction. NYCDOT Chief Bridge Officer Henry Perahia uses an analogy: "It's like rebuilding a car's engine while the car is still running."

Once the designers and engineers figured out a solution to the traffic flow problem, the outreach team created a strategy to inform the public about the reconstruction work, why the work needed to be performed, and, most important, alternate travel routes that could ease disruption to commuter traffic. A major part of any outreach strategy is the message. It is not enough to tell the public that, for the next 2 years, the North Outer Roadways (four of the eight lanes of the Williamsburg Bridge) will be closed. More detailed information is needed. In addition to being informed about the road closure, the public was told why the road was being closed, exactly what work was being done, and the measures taken to mitigate impacts during the reconstruction project.

The public outreach team found that providing accurate and pertinent information on a timely basis not only educated the community, but also built trust and fostered a sense of partnership among bridge users, neighboring communities, and NYCDOT. When residents became confident that the information they were receiving was accurate and reliable, they learned to trust the messengers delivering the message, and from that trust came partnering and greater acceptance of the reconstruction project.

Building Bridges to Local Residents

To reconstruct the North Outer Roadways of the Williamsburg Bridge, it was necessary to close the four North Roadway travel lanes and divert all traffic to the four South Inner and Outer travel lanes. Under this configuration, two-way traffic between Manhattan and Brooklyn was maintained at all times, but the volume across the bridge was cut in half. This reduction in traffic flow was not good news to the motorists driving the more than 140,000 vehicles that cross the bridge daily. The challenge was to present this information to bridge users and obtain their buy-in.

The public outreach team targeted bridge users and residents of local communities, both of whom had their own separate concerns. Bridge users were worried about traffic delays and traveling between Brooklyn and Manhattan, while local residents and merchants were concerned with construction impacts, such as noise, dust, local street closures, and detours.

The first phase of the outreach focused on addressing the concerns of the local community and communicating the mitigation measures that would be implemented. Although bridge users would be affected temporarily by traffic backups, they could drive away from the construction site—but residents of local communities could not. That made it important to address their concerns first, before any major traffic shifts were implemented. By targeting and engaging the local communities first, the outreach team was able to earn local acceptance and support for the project.

Methods of communication included letters, public presentations to the local community boards (similar to town planning boards), and a four-color brochure translated into Spanish and Chinese. The brochure reinforced NYCDOT's commitment to providing timely and pertinent information in a format that is easily understood and attractively designed. A total of 14,000 brochures were distributed, and numerous groups requested additional copies.

Information also was available on NYCDOT's Web site, and a toll-free telephone line provided basic travel updates and allowed callers to leave messages requesting additional information.

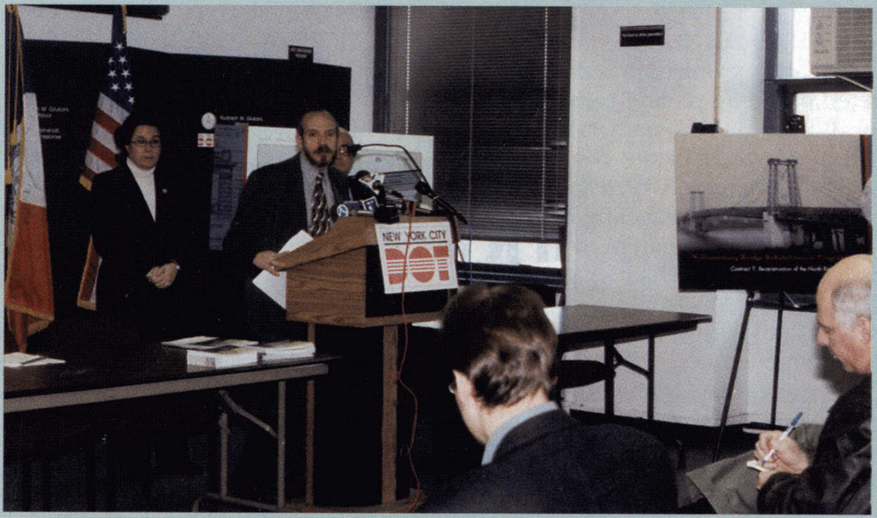
After addressing the concerns of the local community, the public outreach team expanded its efforts by distributing information throughout the metropolitan area. Outlets included emergency service providers, such as hospitals and police precincts, and advocacy groups like the Automobile Club of New York and Transportation Alternatives. Elected officials, borough presidents, community boards, civic groups, merchants, and officials representing business improvement districts also contributed to the outreach effort.

Next, the Bridge Users

The lane change for the Williamsburg Bridge was scheduled to begin on January 29, 2001. Within a month of the scheduled change, getting the word out to bridge users became the priority. The agency planned two major events: a press conference featuring the NYCDOT commissioner and a targeted user handout event. The press conference was held on January 23, 2001, and apparently was successful because the media published no negative stories and no negative public responses were received.

The targeted user handout event took place during the week leading up to the January 29, 2001, closure date. Using a blitz approach,

A motorist's view traveling into Manhattan on the inner roadway of the Williamsburg Bridge.



On January 29, 2001, NYCDOT Commissioner Iris Weinshall (left) and Chief Bridge Officer Henry Perahia (right) address media representatives at a press conference to announce the lane closures on the Williamsburg Bridge.

approximately 20,000 travel advisories were handed out to motorists crossing the Williamsburg Bridge over a period of 4 days. This distribution reinforced the NYCDOT's efforts to ensure that bridge users were well informed.

On the closure date, the transition from eight to four travel lanes went smoothly. Again, no protests took place, and no negative stories appeared in the press. In fact, by providing information to the news media proactively, the public outreach team was able to take advantage of the media's resources for getting the message out. Instead of being the target of negative stories, the project and the NYCDOT were depicted in a positive light for reconstructing the Williamsburg Bridge and preserving a significant segment of New York City's infrastructure.

Community feedback from NYCDOT's efforts was positive. Martha Danziger, district manager for Manhattan Community Board #1, praised the NYCDOT and its project team "for executing a well-structured and proactive outreach program that addressed the needs of the community."

We'll Take Manhattan

The Manhattan Bridge reconstruction project contained two major components that could cause concern: interruption of mass transit service and a roadway closure. The two components were scheduled to occur a year apart.

As with the Williamsburg Bridge project, the transportation inconveniences were not welcome news to the 90,000 subway riders and more than 75,000 motorists who cross the Manhattan Bridge daily. The subway shutdown began on July 22, 2001, and the North Upper Roadway was scheduled to close for reconstruction on August 1, 2002.

The subway closure occurred before the roadway closure, and the outreach team believed that gaining acceptance of the subway closure would make their jobs easier when the time came to gain community acceptance of the roadway closure. Although the roadway closure had not yet occurred at that time, gaining motorists' acceptance of the subway service interruption was essential because the occurrence of any delays in that work would affect the roadway closure adversely.

A closeup view of the Brooklyn Tower of the Manhattan Bridge shows the Manhattan skyline in the distance.

The temporary closure of the subway tracks on the north side of the bridge to reconstruct the framing structure posed one of the greatest challenges. This service interruption required the closure of the Grand Street Station in Manhattan, and, as a result, trains were rerouted to alternate tracks. The station's closure was a major point of contention for the Lower East Side neighborhood of Chinatown. Although the service interruption aspect of the project was under the purview of New York City Transit, the NYCDOT was responsible for overseeing the construction work and conducting a successful public outreach program.

The public outreach program for the Manhattan Bridge project began in March 2001 and took a similar approach to the one used successfully for the Williamsburg Bridge. One of the greatest challenges in gaining community support was to reverse any negative perceptions. The community had heard of the subway station closure months in advance and had been protesting to the transit agency, NYCDOT, and the Governor. Although the transit agency would handle notification of changes in subway service, NYCDOT needed to perform the initial phase of the public outreach program successfully and lay the groundwork for the North Upper Roadway closure that was scheduled to occur in August 2002.

The public outreach kicked off with an introductory letter to New York City's community boards. The letter provided an overview of the project, outlined the schedule, and described impacts to the traveling public. NYCDOT assigned a community liaison person to the project and installed a telephone line to handle questions from the public during nonconstruction hours. The telephone line also provided travel-related information. NYCDOT devel-

The pedestrian walkway over the Manhattan Bridge.

The North Upper Roadway of the bridge.

oped a brochure and a Web site to keep the public informed. Again, the brochure was translated into Spanish and Chinese and formatted for the NYCDOT Web site (www.nyc.gov/calldot). The brochures were distributed citywide to community boards, elected officials, and merchant and civic groups.

The project came under increasing public scrutiny in the weeks leading up to the subway shutdown. NYCDOT and the transit agency coordinated their efforts to brief elected representatives and notify the public of the upcoming service changes and impacts. The collaborative effort was important in creating a single voice to handle communications.

The results proved beneficial to all involved. A week before the scheduled shutdown, the Governor authorized implementation of a shuttle service between Grand Street and Broadway-Lafayette. The community saw this as a positive solution to handling the commuting problem. Similar to the target user handout event on the Williamsburg Bridge, the transit agency staff held an information event a few days following the shutdown, where the staff distributed thousands of travel advisories.

A Brooklyn Community Board #9 representative who called the telephone information line to inquire whether there was a misprint in the brochure regarding the date of the North Upper Roadway closure was pleasantly surprised to learn that she was being informed a year early of the intended road closure.

The second phase of the project—the road closure—occurred as scheduled in August 2002, with the media reporting the closure as a necessary part of the rebuilding program. Hasan Ahmed, director of the NYCDOT East River Bridge program, attributes the success of the outreach effort to the "positive groundwork that was laid in 2001 and the subsequent efforts in 2002, which included the distribution of more than 20,000 travel advisories in the 5 days leading up to the closure."

In June 2003, the reconstructed bridge roadway was reopened to traffic, 61 days ahead of schedule. Communications were the key to the success of the NYCDOT rehabilitation of the Williamsburg and Manhattan bridges. Communicating messages to customers, communities, and other constituencies resulted in an outreach program that was beneficial to all involved.

Detail of the "Spirit of Industry" sculpture on an arch in the plaza of the Manhattan Bridge.

Alexandra Zetlin, the founder and president of Zetlin Strategic Communications, Inc., has more than 20 years experience in the development of public/community participation programs, transportation policy planning and coordination, and media relations. For the last 16 years, Zetlin has specialized in the development and implementation of successful communications strategies to advance government agency and corporate goals. She has a master's of business administration degree from Columbia University and a bachelor's degree from Vassar College.

Shane Ojar is the manager of planning and studies for Zetlin Strategic Communications, Inc. He has more than 10 years' experience managing community outreach programs. Ojar's approaches to planning and design of construction projects involve combining the needs of diverse communities with technical components. He has been successful in developing outreach programs that identify and educate stakeholders and create consensus among diverse communities and agencies. He has a bachelor's degree from New York University.

by William S. Jones
and Bob Rupert

511—It's Happening!

Here's an update about the three-digit dialing code for traveler information being implemented and gaining momentum around the country.

In July 2000, the Federal Communications Commission assigned 511 as the three-digit dialing code for traveler information. Nearly one year later, the first 511 system began operating in northern Kentucky and the Cincinnati, OH, metropolitan area. Since then, the number of 511 systems popping up around the country has continued to grow steadily.

Seventeen locations had launched services as of June 2003, including 12 statewide systems, 4 in metropolitan areas, and 1 regional service. All told, the systems in operation today provide access to traveler information to more than 14 percent of the Nation's population. By the end of 2003, another 7 States and 1 metropolitan area expect to launch 511, extending the reach of the three-digit number to more than 25 percent of the country.

The launches in 2003 also expanded the reach of 511 to a larger proportion of rural America. As North Dakota Governor John Hoeven noted during his State's launch event, "You can pick up the telephone, hit 511, and find out all kinds of information that makes it safer for North Dakotans to travel."

In another rural State, Michael Jackson, with the Iowa Department of Transportation, anticipates improved safety for motorists. He notes that "511 provides a safety net for those who travel on Iowa's interstate and U.S. highway routes."

During the statewide launch of Kentucky's 511 services, Governor Paul Patton noted the range of motorists who will benefit, saying that the service "will assist commuters, vacationers, highway travelers, and the trucking industry in finding the quickest and safest way to get from point 'A' to point 'B' in Kentucky."

Deployment Coalition

To assist States planning to implement 511 services, the Federal Highway Administration (FHWA) provided $4.4 million to 43 States and the District of Columbia, starting in 2001. States used their grants to convene stakeholders, learn from the experiences of early deployers, acquire planning services from consultants, and develop plans for implementing 511 services.

In early 2001, the U.S. Department of Transportation (USDOT), the American Association of State Highway and Transportation Officials (AASHTO), the American Public Transportation Association, the Intelligent Transportation Society of

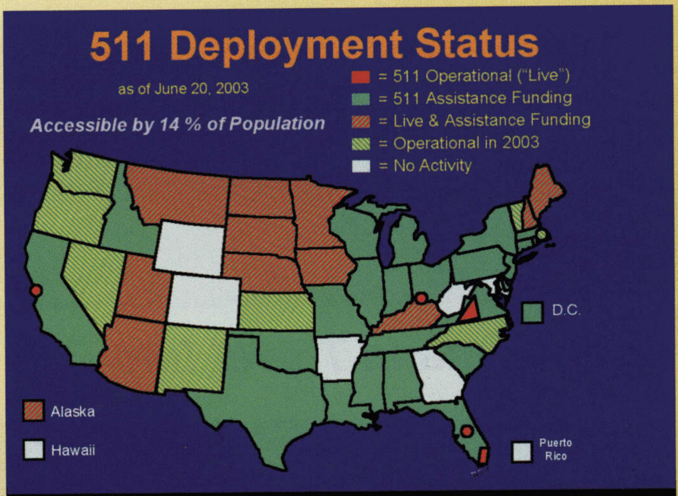
(Above) Highway signs like this one in California direct motorists and bus passengers to call 511 for travel information. ***Photo: Metropolitan Transportation Commission.***

Kentucky Transportation Cabinet

Governor Paul E. Patton answers questions during a press conference on the statewide launch of 511 services in Kentucky.

America, and a number of other organizations formed the 511 Deployment Coalition. From the outset, the goal of the public-private coalition was "the timely establishment of a national 511 traveler information service that is sustainable and provides value to users."

The national associations represented on the policy committee (the governing body of the program) intend to implement 511 nationally, using a bottom-up approach facilitated by information sharing and cooperative dialogue. By sponsoring strategic model deployments, developing and distributing marketing materials and deployment reports, and developing standards to facilitate nationwide interoperability, USDOT and the 511 Deployment Coalition are greasing the skids to help bring traveler information to a telephone near every single U.S. motorist.



Source: FHWA

This map shows the extent of 511 deployment in the United States. As of June 2003, 14 percent of the population could access traveler information through 511.

Operational Statistics

Current projections show that deployment coverage by 2005 will exceed the 511 Deployment Coalition's goal of reaching 25 States, 30 of the largest 60 metropolitan areas, and more than 50 percent of the Nation's population—roughly 145 million. With the launch of the new services, 511 usage is up as well. More than 8 million calls were made nationwide since June 2001, raising usage 200 to 400 percent compared with June 2000.

Although the number of monthly 511 calls varies due to changing weather and road conditions, call centers receive more than one-half million calls each month. The coalition expects 511 usage to show growth trends comparable to those of Web sites as the availability of service increases and marketing improves.

Deployers expect that 511 will show the greatest growth in metropolitan areas in 2004 and 2005. The largest metropolitan area to launch 511 services as of 2003 is the San Francisco Bay area, with a population of more than six million. The Metropolitan Transportation Commission is responsible for 511 services in the Bay area, building on its successful TravInfo® traveler information system. The program in the San Francisco Bay area provides more transit information than any other 511 system in the country, with 28 public transit agencies participating. The Bay area also provides airport information through its service and plans to offer route-specific travel times as the system evolves.

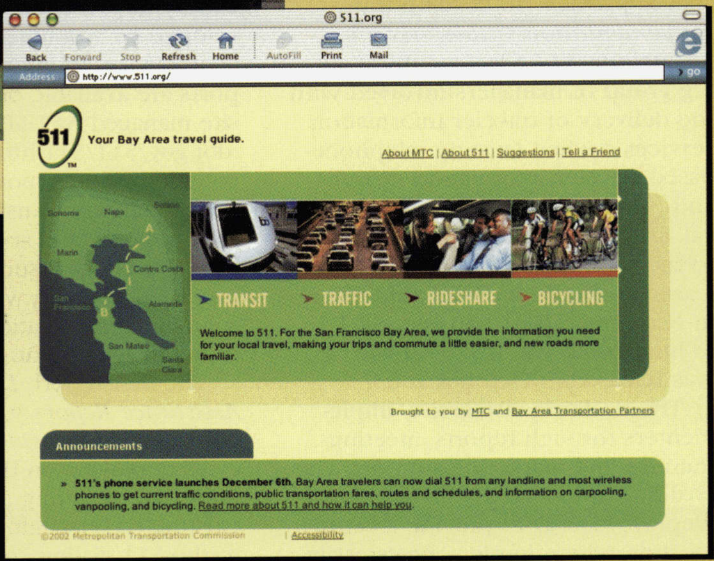
"We're giving control back to the people," U.S. Representative Ellen Tauscher noted during the Bay area launch. "We're giving them good information in a timely and predictable way so that they can make good choices for themselves and their families."

Model Deployments

In 2002, FHWA selected Arizona to develop a model deployment of 511 services. Arizona will enhance its early 511 service by adding state-of-the-art features such as information on route-specific weather and roadway conditions,

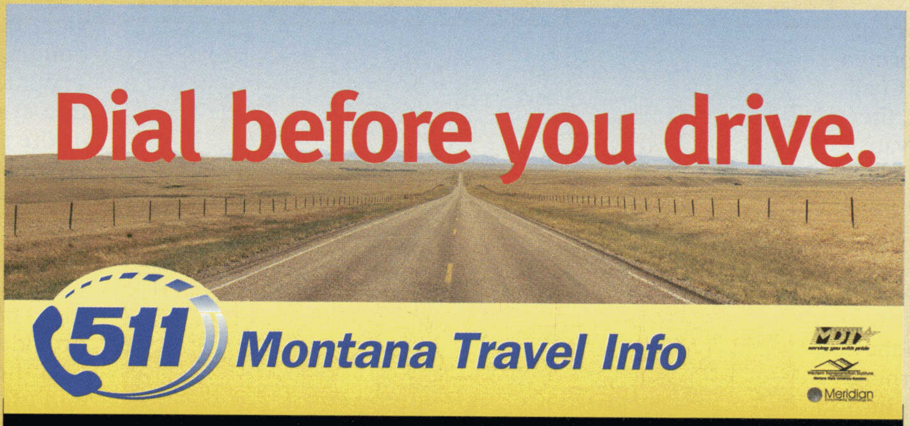
Metropolitan Transportation Commission

U.S. Representative Ellen Tauscher talks with reporters at the December 2002 launch event for 511 services in the San Francisco Bay Area.



Metropolitan Transportation Commission

The San Francisco Bay Area Web site for 511 (www.511.org) offers travelers information for getting around the Bay Area via transit, highway, bicycle, and carpool.



A billboard produced by the Montana Department of Transportation recommends that motorists call 511 before traveling.

Montana DOT

voice-recognition telephone services, a trial of real-time transit arrival times, and a test of real-time arterial travel information. Arizona's enhanced deployment began in October 2003, and a 12-month national evaluation will follow. The results of the evaluation will provide valuable information for other locations that are designing and installing 511 services. One of the most useful results of the evaluation may be a consistent method for analyzing customer satisfaction.

Also, 511 services will receive a major boost from activities associated with the Surface Transportation Security and Reliability Information System Model Deployment that USDOT awarded to Florida in early 2003. One of the major aspects of the model deployment—known as *iFlorida*—is the development of statewide services tying together the local 511 services available in Orlando, Miami, and soon in Tampa.

Marketing Materials

To help States and metropolitan areas organize and launch their own 511 services, the coalition developed guidelines on the information (content) and the degree of uniformity (consistency) that basic services should provide. To develop the *Implementation Guidelines for Launching 511 Services*, the working group of managers involved with the delivery of traveler information services studied existing telephone-based traveler information systems and projected technological, political, and economic factors pertinent to the services. The coalition released version 1.0 of the guidelines in November 2001 and version 1.1 in June 2002. The latest version, 2.0, was released in October 2003.

The coalition also assists implementers through reports, meetings, training, and marketing support. The coalition launched a Web site (www.deploy511.org) to provide a central location where implementers easily can find information developed by the coalition and specific locations that have launched 511 services.

The coalition developed a toolkit of marketing materials that local implementers can use to publicize the launch of their 511 services and promote them. By using these ready-made materials, States and metropolitan areas can avoid reinventing the wheel as they develop marketing campaigns for their services. Promotional materials developed by 511 implementers include brochures, press kits, public service announcements, videos, and roadside billboards. Implementers can access the official 511 logo and the promotional materials at www.deploy511.org/marketing.htm.

Deployment Assistance Reports

Among the most useful products published by the coalition are the deployment assistance reports. Developed by volunteers from the coalition's working group, the reports are available on the 511 Web site managed by USDOT at www.its.dot.gov/511/511.htm. Report topics include business models and cost considerations, transfer of 511 calls to 911, homeland security, regional interoperability issues, public transportation content, weather and environmental information, and quality of roadway content.

The first report, *Deployment Assistance Report #1: Business Models and Cost Considerations*, educates deployers on the issues involved in migrating a planned or existing traveler information service to the 511 dialing code. Business models and cost recovery are critical factors for determining the sustainability of the 511 service.

Considerable discussion between coalition members centered on the desirability and implications of enabling traveler information systems to transfer true emergency calls (that is, 911 calls) made to 511 in error. To transfer the call requires that certain capabilities exist within the 511 system. *Deployment Assistance Report #2: Transfer of 511 Calls to 911* explains the steps involved in transferring emergency calls, the technical and cost implications, and the potential legal issues that might be involved.

The report on homeland security, *Deployment Assistance Report #3: 511 and Homeland Security*, examines the role that 511 can play in assisting in homeland security efforts and the impact that emergency preparedness could have on 511 services. This report discusses the challenges and opportunities for 511 systems, their designers, and operators arising from the terrorist attacks on September 11, 2001. Neither New York City nor the Washington, DC, metropolitan area had a 511 system, but authorities learned many relevant lessons. Although the report does not provide solutions, it does highlight the issues and suggests related guidelines.

The report on regional interoperability, *Deployment Assistance Report #4: 511 Regional Interoperability Issues*, offers implementers technical advice on how to deal with callers who want information on transportation facilities and services outside of the area served by their 511 system. Callers may not know which jurisdiction they are in, or where the boundary for the next jurisdiction is, but they want information about the travel conditions ahead of them. This report can help deployers integrate and improve the operation of services between State borders and within States where metropolitan and statewide systems overlap.

The goal of 511 is to provide multimodal travel information, so transit properties are key stakeholders. *Deployment Assistance Report #5: Public Transportation Content on 511 Systems* shares implementation experience and lessons learned related to providing content on public transportation and transit through 511 services.

Whether traveling by car, rail, bus, bike, or foot, travelers need prioritized information on current and anticipated weather and road-weather conditions. *Deployment Assistance Report #6: Weather and Environmental Content on 511 Services* explains how deployers can gather and disseminate information on current and future forecasts and travel conditions that are likely to affect travel. To ensure consistency across 511 systems, the report recommends providing weather forecasts from the National Weather Service at the National Oceanic and Atmospheric Administration, plus mobile and stationary data gathered by maintenance and operations personnel.

For many traveler information services, the preponderance of callers are interested in roadway conditions, so the quality of roadway-related content will in many cases dictate overall satisfaction with the service. *Deployment Assistance Report #7: Roadway Content Quality on 511 Services* provides the most up-to-date guidelines, state-of-the-practice implementation experience, and lessons learned related to gathering and providing quality roadway content.

Emphasis on Interoperability

Based on the experiences of early deployers and ensuing technical discussions among coalition members, national interoperability—the ability of 511 services to work seamlessly across the country—is a significant issue. It first arose in 1998 when Congress requested that USDOT provide a report on the standards the Department considered "critical" to national interoperability. That report, *Intelligent Transportation Systems: Critical Standards,* issued in June 1999, included standards for Advanced Traveler Information Systems (ATIS) among those critical to national interoperability.

Discussions among coalition members about the fundamental nature of abbreviated dialing codes like 511 triggered increased interest in interoperability. Codes like 511 and 911 are not national numbers. That is, a caller cannot dial an area code with 911 and get the emergency services within that area code. The public-switched telephone network is not wired to recognize that dialing sequence; therefore, 511 is a local service. Although the definition of *local* may be extended to include a large metropolitan area or an entire State depending on how the system is designed, ultimately when the customer moves from one 511 service area to another, the challenge is to ensure a seamless transition of 511 services. *Deployment Assistance Report #7*, discussed above, deals with this issue in some depth.

The issue of national interoperability highlights a real and immediate operational need: If 511 service providers in adjacent areas are going to exchange data, then a national standard for data must be established. Toward this end, as part of the new reauthorization proposal, USDOT proposed legislation that would require the Department "to establish a national data exchange format." In parallel with this legislative initiative, the Intelligent Transportation Systems (ITS) Joint Program Office at USDOT is finalizing a new ATIS standard, known as the Society of Automotive Engineers' standard 2354. The new standard uses Extensible Markup Language (XML), which is the language of choice among 511 deployers and public agencies offering traveler information on the Internet.

Although some 511 deployments use formats other than the ATIS standard, USDOT is committed to working with these deployers to achieve compatibility. Additionally, USDOT encourages public agencies not yet operating 511 to use the ATIS standard. The purpose of all these efforts is to achieve national interoperability.

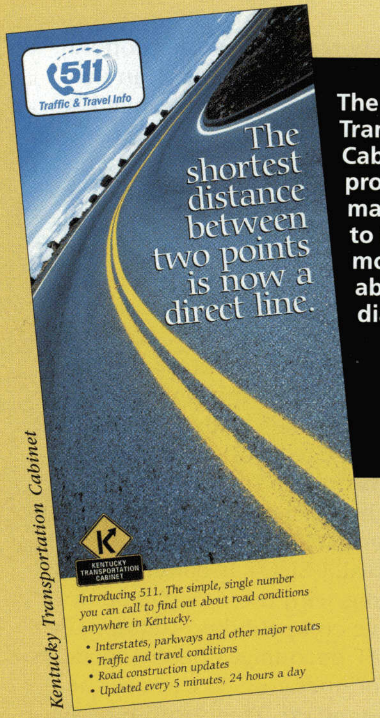
Another key element of the reauthorization proposal is a requirement for all States to "establish a statewide incident reporting system." More than simply reporting traffic incidents, a statewide system should provide data on all constraints that impede traffic. This would include crashes, disabled vehicles, weather-related constraints, maintenance activities that result in the closure of road segments or lanes, and special events that impair the transportation network. Further, the incident data should be in *near* real time, that is, within a couple minutes of an event. This definition of incident reporting likely will require coordination between transportation agencies and the State police, at a minimum. Coupled with the requirement for a standard data exchange format, a statewide system for incident reporting will help national interoperability become a reality.

Virginia DOT

Statewide news coverage followed the February 15, 2002, launch of the 511 system along the I-81 corridor in Virginia.

New ATIS Standard

Taking advantage of the lessons learned from



Kentucky Transportation Cabinet

The Kentucky Transportation Cabinet produced this marketing flyer to inform motorists about the 511 dialing code.

existing deployments will make the initial ATIS standard more robust and, hopefully, more meaningful. Arizona, selected by USDOT as a 511 model deployment State, is using the standard to implement its statewide incident reporting system in XML. Other deployers will benefit from this experience, which will be fed back into the development of the ATIS standard.

The standard contains all the messages and data elements likely to be required for a 511 system or other delivery mechanism for traveler information. The standard contains four principal message types:

1. Requests for traveler information pertaining to a specific route or location
2. Requests for driving instructions and/or transit routing information
3. Responses to information or route requests
4. Advisory broadcast messages containing traveler information

These four message types contain all the information that will be valuable to travelers. Supporting the messages are all the data elements that operators need to define the specific information being requested or provided in response to a request.

The Society of Automotive Engineers also is developing a user's guide for implementing 511, and a training seminar now is available to assist deployers.

Filling the Information Gap

A traveler information system is only as good as the data available on the transportation network. Traditional surveillance of the network is unlikely to provide the real-time data necessary to support either traveler information systems or the effective real-time management of the network. Therefore, a major thrust of the *iFlorida* project is to use innovative techniques to obtain real-time data on all freeways and major arterials. The *iFlorida* project will provide travel times by road segment by employing vehicle probes, such as toll tags and license plate readers, extensively throughout the Orlando area to gather travel times.

In the long run, using vehicles as probes to provide information on the real-time status of the transportation network is the most likely approach to gathering the desired data. USDOT, therefore, continues to explore new technologies that offer the potential to use vehicles as probes. The Department is evaluating two different approaches that involve obtaining data using cell phones. In addition, USDOT expects that further research could lead to the holy grail of traveler information—travel times for specific road segments.

Florida DOT

An operator at the Regional Traffic Management Center in Orlando, FL, monitors cameras on I-4 and updates the 511 traffic advisories.

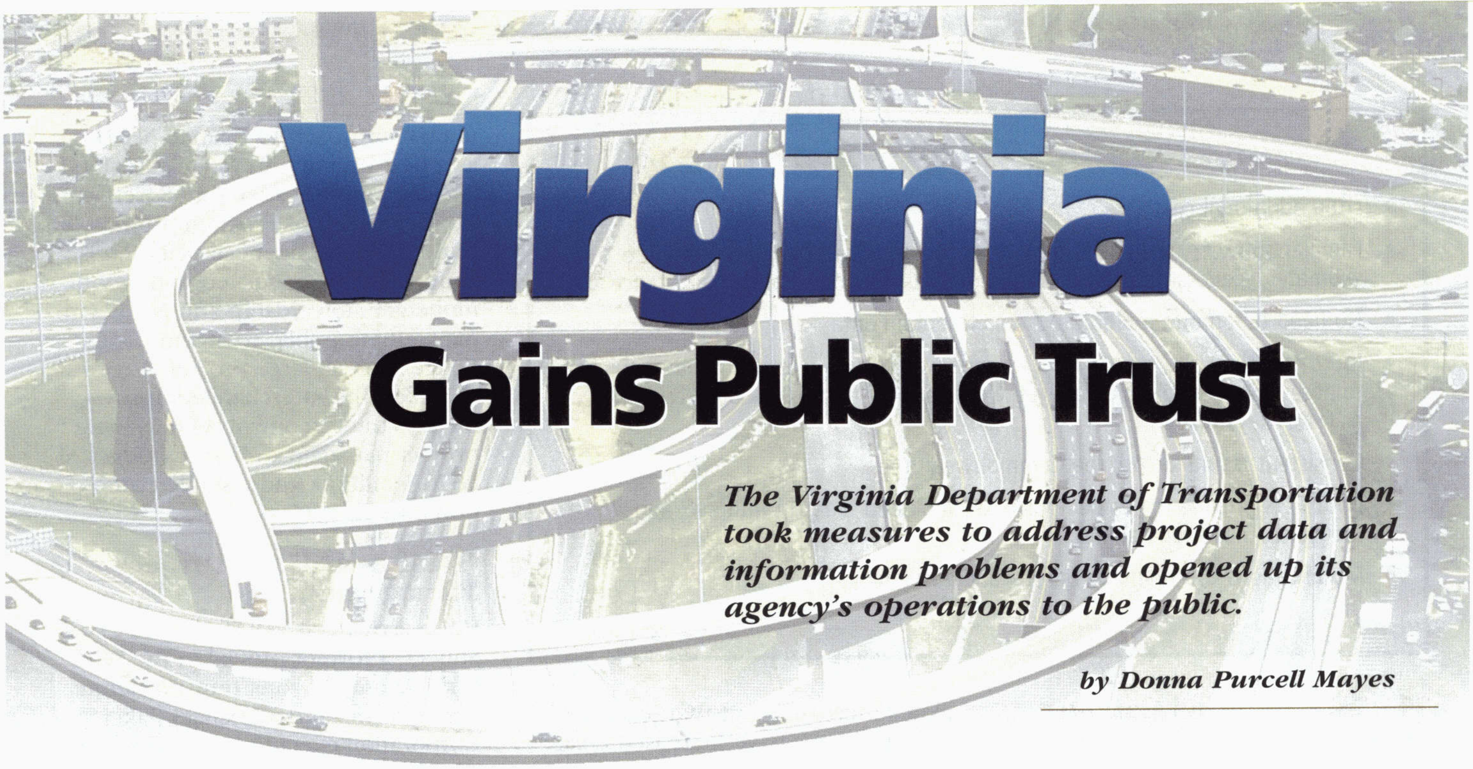
The coalition expects that additional probe technologies will be implemented and evaluated during the *iFlorida* project. As vehicles contain more information technology capabilities, and with the deployment of other communications technologies, such as Dedicated Short Range Communications and third generation cellular, multiple approaches for probe purposes may become feasible.

"Good data are the key to effective traveler information," says Jeff Paniati, associate administrator for operations at FHWA and acting director of the ITS Joint Program Office at USDOT, "whether it be for 511, the Internet, or other means of communicating with the traveling public."

William S. Jones oversees all technical activities in the ITS Joint Program Office. Prior to joining USDOT in 1995, he spent 34 years with Westinghouse Electric Corporation in the defense and commercial electronics business. Jones has a master's degree in electrical engineering from Washington University in St. Louis, MO, and an MBA from The George Washington University in Washington, DC. He is a registered engineer in Maryland.

Bob Rupert is the technical programs coordinator for the Office of Transportation Management in FHWA's Office of Operations. He currently manages the traveler information program and serves as program manager for the 511 telephone number. Previously, Rupert managed the TravTek operational test of in-vehicle navigation in Orlando, FL, and led several other ITS projects dealing with traveler information.

For more information, visit www.deploy511.org or www.its.dot.gov/511/511.htm, or contact Bill Jones at 202-366-2128, william.s.jones@fhwa.dot.gov, or Bob Rupert at 202-366-2194, robert.rupert@fhwa.dot.gov.



Virginia Gains Public Trust

The Virginia Department of Transportation took measures to address project data and information problems and opened up its agency's operations to the public.

by Donna Purcell Mayes

Says author William Pollard, "Information is a source of learning. But unless it is organized, processed, and available to the right people in a format for decisionmaking, it is a burden, not a benefit."

The Virginia Department of Transportation (VDOT) found itself in such a situation; it had a big problem with data and information management, which led to other more serious problems. On the one hand, VDOT took pride in being known as an innovative engineering and research leader to peers in the transportation industry. However, VDOT also discovered that Virginia's elected officials, reporters, and citizens didn't necessarily retain the same view and positive impression, especially when it came to construction projects.

Within the agency, there appeared to be a disconnect between data collections and the information that was needed, desired, and communicated internally and externally, contributing significantly to budgetary and project management issues, and a negative outward image. Part of the difficulty was where information was stored, access to that information, and what information was needed to enable managers to make proactive decisions. Volumes of data, past and present, were stored in a variety of methods, locations, and databases, making it onerous to gather and analyze information about one project, much less all projects. Problems with cost estimating also could be linked to inaccurate, incomplete, and "guesstimated" information.

"Project management and cost estimating were our two biggest trouble spots," says VDOT Commissioner Philip A. Shucet. "I asked about several major projects' costs and progress. Each person I asked gave me different answers because each answer included different data . . . presented in such a way that it was hard to get a good handle on what was really going on with the projects."

He adds, "You can't do good business that way, so we developed our project management system, Dashboard, and our Cost Estimation System within a year, and we're already reaping the benefits . . . huge leaps from where we were."

Through these two new Web-based systems developed in-house with off-the-shelf software, VDOT is gaining public trust and a reputation for accountability and openness.

A VDOT project manager uses Dashboard to track progress on his projects. Local government officials, contractors, and citizens can do the same by visiting Dashboard at virginiadot.org.

All photos courtesy of Virginia Department of Transportation.

Benefits of Dashboard

- Little additional cost
- Familiar software, such as Excel worksheets to collect data and compute estimates, reduces demand on information technology staff for assistance
- No need to log into multiple systems to obtain data
- More complete and timely data, no time wasted trying to locate data, ability to access data from any employee workstation within 60 seconds and in 10 or fewer keystrokes
- Consistent results across the Commonwealth
- Both sites provide the same "business" look and feel, are intuitive, and reduce the need for training
- Modifications can be made quickly and easily by in-house staff

The Mixing Bowl Catalyst

The VDOT problems came to light with an improvement project near Washington, DC, for the I-95 Springfield Interchange, known locally as the "Mixing Bowl." According to an audit report about the project from the U.S. Department of Transportation's (USDOT) Office of the Inspector General (OIG), "The Springfield project, when completed, will improve traffic flow at the junction of Interstates (I)-95, 395, and 495 in Fairfax County, VA, which is one of the busiest and most congested interchanges in the country." The massive interchange feeds I-95 traffic into the District of Columbia, northern Virginia, and Maryland through I-395 and I-495. Like sometimes happens with other complex urban projects, this huge, seven-phase effort with its frequently changing costs and scope was starting to pick up a negative perception.

The project's estimated cost in June 1994 was $241 million, however, this increased by 180 percent to at least $676.5 million by June 2002, according to the OIG's November 2002 *Audit of the Springfield Interchange Project: Federal Highway Administration Report Number (IN-2003-003).* The audit also maintained that "this 180 percent cost increase occurred due to (1) the addition of new features after the initial estimates were prepared, (2) consistent exclusion of certain reasonably anticipated and known costs from earlier estimates, and (3) unanticipated cost increases."

The audit found that not only had the Springfield project cost estimates increased, but that "construction problems have increased costs and could delay project completion, and funding to pay for cost increases has come at the expense of other State highway projects. We [Office of the Inspection General] made six recommendations to improve planning, cost-estimating, project management, and oversight. Responding to a draft of this report, FHWA [Federal Highway Administration] agreed to implement all six recommendations. VDOT also agreed with all of the recommendations and committed to work with FHWA to implement them."

Because of its problems, the project served as a catalyst for VDOT to make major changes in how the agency manages highway and bridge construction projects. It set the stage for real change in the agency that would be viewed as permanent instead of political. VDOT considers the changes to be groundbreaking, because they demonstrate how a State agency can do business openly under the unblinking public eye.

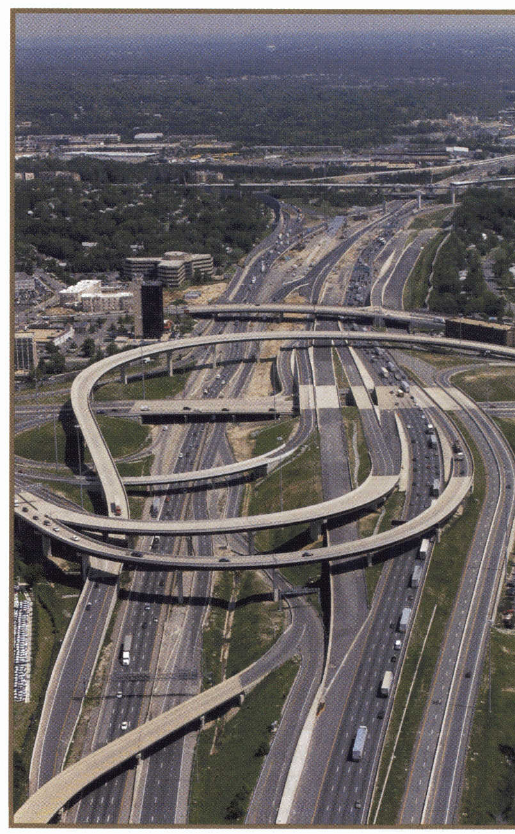
"Also significant is the fact that Virginia is now requiring finance plans for all [its] large projects, not just the federally mandated plans for megaprojects. The Office of Program Administration views Virginia's 'voluntary' approach to finance planning as a best practice," says Stewardship and Oversight Leader Tom Sorel from FHWA's Office of Program Administration. "Sound financial planning is almost always associated with good monetary stewardship and is a key to maintaining public trust and confidence with all large projects."

Today, the interchange improvement is under control with a single project manager, a realistic budget of $676.3 million, and a stable completion date in 2007.

"Dashboard" for Project Management

Upon arriving at VDOT in April 2002, Shucet, a former official in the West Virginia and Arizona transportation departments and a Michael Baker Corporation executive vice president, asked his new staff members if they had any way of telling how VDOT was doing with its projects and program deliveries. Their responses indicated that this was an area for agency improvement.

Dr. Gary Allen, VDOT's chief of Technology, Research, and Innovation, wondered if a simple tracking tool with colored lights, or something similar, to show the status of every project in VDOT's Six-Year



As this aerial shot suggests, the massive Springfield Interchange Improvement Project near Washington, DC, is a highly visible effort that motivated VDOT to change the way it manages and estimates its projects.

Improvement Program might do the trick. After talking through the idea and working with a handful of people, Allen quickly—and literally—sketched out the concept. The group also came up with an initial set of rules to determine project statuses. Within less than 2 weeks, the group presented a template for what became VDOT's project management tool, Dashboard.

The agency's Dashboard is an online, one-stop information source that highlights the status of Virginia projects ready to go to construction and those under construction. Dashboard shows the latest on a project's progress, costs, and work orders (contract approvals to move forward with the work). The statuses are pictured using the red, yellow, and green lights on a traffic signal icon:

- *Green* means the project is on track—on time, within budget, and has zero or few work orders.
- *Yellow* means the project is at risk of falling behind, going over budget, or having too many work orders.
- *Red* means the project is behind, over budget, or has too many work orders.

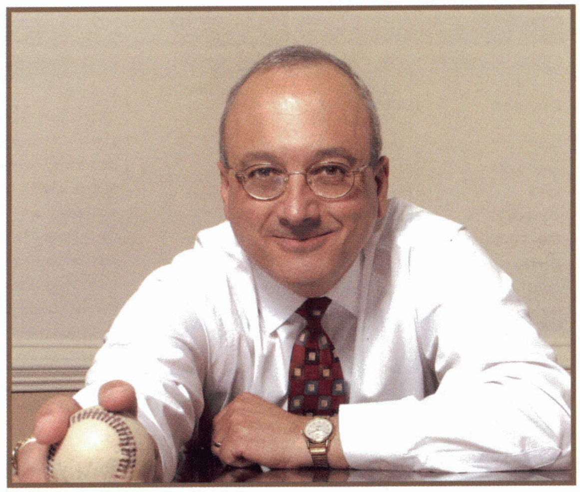
"Our goal is to maintain the green, manage the yellow, and deep-six the red," says John DePasquale, P.E., northern Virginia construction engineer. To do that requires spending resources, with "yellow" generating the biggest cost-to-benefit ratio in moving a project to "green," he explains.

The tool earned its name because, just as an automobile's dashboard keeps the driver informed of the car's performance, Dashboard keeps VDOT project managers (and the public) tuned in to construction performance. It alerts them to the projects that are on track and those that are at risk. With this information at their fingertips, the project managers' jobs are to get the work back on track when possible.

"It's a great tool," says Tom Hawthorne, P.E., VDOT's Richmond District administrator. "Dashboard lets us focus on simple metrics to judge our progress, good or bad, against our goal of managing our transportation program more effectively."

How Dashboard Works

Dashboard graphically displays information collected from several mainframe systems through a data warehouse. Those systems include VDOT's Program Project Management System, showing the status of project schedules from planning to advertisement, and Trns·port, a construction contract monitoring system developed by the American Association of State Highway and Transportation Officials (AASHTO). Because the systems are updated and queried daily, the Dashboard view is always less than a day old.



VDOT Commissioner Philip Shucet encourages employees to always keep their "eyes on the ball." The new Dashboard tool enables employees to manage projects more effectively.

"It tells me in a moment what would have required going through reams of individual project reports to pull together before," says Connie Sorrell, VDOT's Director of Policy and Organizational Development who was tasked with coordinating the Dashboard effort. "Before Dashboard, we were data rich, but information poor."

VDOT's Chatham Resident Engineer Randy Hamilton adds, "Dashboard helps us easily track a project from advertisement through construction and keep it moving forward. Before, we had to rely on others to go through various information systems to pull the information together. Now we can get it ourselves quickly and we can answer our customers' questions on details."

No special software was developed or purchased. VDOT's information technology staff relied on Microsoft® software products already used by the agency.

Dashboard has three views: a summary level, a second level that lists the projects, and a third with project details. The levels are on VDOT's external Web site, but within the third is a section reserved for internal viewing that includes some project history. To view the Dashboard system, go to http://dashboard.virginiadot.org on the Web. Projects can be sorted into

Technical Specifications

Both systems:

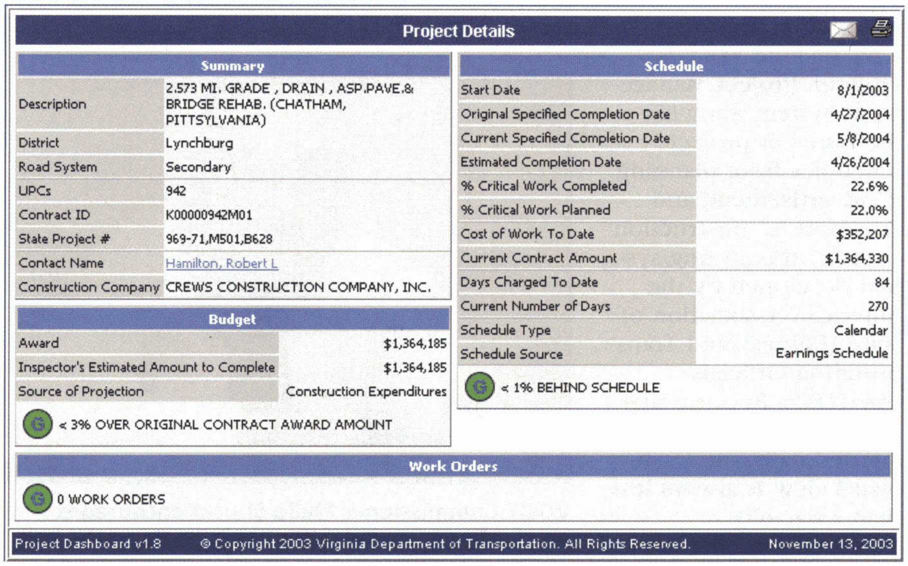
Microsoft Windows® 2000 Server operating system
Microsoft Internet Information Server (IIS), a Web application server
Microsoft SQL Server™ database
Microsoft SQL Server 2000 Data Transformation Services (DTS) for Enterprise Application Integration
Rapid Application Development (RAD) tools and methodologies

Dashboard:

Microsoft Visual Basic® COM component, a dynamic link library (DLL)
Microsoft Active Server Pages (ASP), server-side scripting environment, Visual Basic Scripting

Cost Estimation System:

Microsoft Excel for cost-estimation rules engine and data entry
Microsoft Project office project management program to display project schedules as Gant Charts
Microsoft Exchange for up-to-date user e-mail addresses and phone numbers



This screen shot of Dashboard shows project details to the public, including e-mail links to people accountable for projects. Surprisingly, VDOT managers were not flooded with angry comments, but instead received reasonable questions and compliments.

statewide, regional, local, or highway system listings. The system is transparent: anyone can see the information without a password.

Project status is reported in four categories:

- Advertisement schedule
- Construction contract deadline
- Construction contract award amounts
- Work orders

One of the major challenges in creating Dashboard was establishing criteria that would determine whether a project was "red," "yellow," or "green" in each of the four categories. A project is considered "green," for example, if it is on schedule according to its contract; "yellow" if it is between 1 and 9 percent behind schedule; and "red" if the contract's completion date has passed, or if the project is 10 percent or more behind schedule, or if 90 percent of the time for the project has lapsed but less than 90 percent of the work is complete, or if critical data about the schedule are missing.

Missing or out-of-date information was the other big challenge. Dashboard tracks about 24 of the most significant project activities in VDOT's Program Project Management System. When Dashboard went live internally, many projects that showed up "red" really were simply missing some data. VDOT staff spent several weeks on updating data, and additional time testing Dashboard.

Public Reaction

Less than a year later, on March 12, 2003, and with more than a little admitted internal squeamishness about opening itself up for public scrutiny, VDOT launched Dashboard on its external Web site, www.virginiadot.org.

"It just made sense that if we were spending $3 billion of taxpayers' money a year, they had a right to see how it was being used and to ask questions of the person responsible for the project," says Shucet. "Yes, it made some of our folks nervous, but we have to be accountable for what we do. No excuses. No hiding."

Others agreed. Instead of receiving verbal derision for its "red light" projects, VDOT heard praise for sharing the good, bad, and even ugly details with the public.

"I think it's the most advanced instance of a really transparent project management system," says Jonathan Gifford, director of Master's in Transportation Policy, Operations, and Logistics at George Mason University in northern Virginia.

"In the public sector, it is difficult to know how a project is developing," says Jim Comstock, of Comstock Communications Concepts, a project management expert who has conducted training in several State DOTs, including VDOT. "VDOT's Dashboard is on the cutting edge in providing the needed information to all of the project's stakeholders."

Dwight L. Farmer, deputy executive director for transportation for the Hampton Roads (VA) Planning District Commission, adds, "The public's as well as the (local) governments' opinion of VDOT was that progress and budgets were a great mystery, at best. Dashboard has added enormously to the openness and ease of availability of budget and progress information."

"Governor Warner is a firm believer in 'that which gets measured gets done,' says Virginia Secretary of Technology George C. Newstrom. "VDOT's Dashboard is an excellent example of how State agencies can allow our customers, the citizens of the Commonwealth, to gauge our performance in serving them."

Comments from news reporters and editors include: "Lots of great information, very transparent—you don't get this a lot in government."—Lane Ranger column, *Potomac News*, March 17, 2003. "Transportation Commissioner Philip Shucet says he expects a lot of feedback because of the site. Here's some: Good job."—*Richmond Times-Dispatch* editorial, March 20, 2003.

"The ability to immediately review the physical and fiscal condition of a particular project aids in communicating with my constituents regarding VDOT projects," says Virginia State Senator Marty Williams, who, as chair of the Virginia Senate Transportation Committee, receives many questions about the transportation agency's work. "VDOT employees are aware of their actions, and the quality of their projects is only a few clicks away from their potential critics." The system makes employees aware of accountability for their actions.

Sharing Dashboard on the Web means that users can obtain the details at their convenience. And anyone can ask questions of the project managers through e-mail links contained in each project's description.

"The way Dashboard is presented, anyone can pick up information without having to get hold of someone between 9 and 5," says Young Ho Chang, P.E., director of transportation for Fairfax County, a densely populated area just outside Washington, DC.

"Dashboard is another way for VDOT to improve its relationships with local government and citizens," Chang observes. "I respect VDOT for saying, 'Here's what we're doing and how we're doing it . . . You're going to see us every step of the way.' The true benefit will come with what VDOT does with the information. The key is to improve by using this tool."

Resulting Changes

Shucet agrees and emphasizes that seeing red lights on Dashboard can only help VDOT project teams. "There's nothing wrong with a light being red," he wrote to VDOT employees.

"If a light is red, and if all of the information turning the light red is accurate, then we can learn from the experience to make the next job better. And the one after that even better again . . . That's using knowledge to improve our business," he emphasized.

"Dashboard has been an organizational catalyst for us," adds DePasquale. "It's making everyone focus on the same goals, and it's changing our project management behaviors and practices."

For example, Dashboard and other reports clearly showed that VDOT was doing a better job of keeping its projects within budget, with some notable exceptions, than completing them on time. Three months after Dashboard's public launch, 72 percent of the projects shown were within budget while only 35 percent were within their contract deadlines.

Many of the projects have "calendar day" contracts, meaning that they must be completed within a certain number of days, instead of "fixed date" contracts, which must be completed by a certain date. Now VDOT is transitioning to all fixed-date contracts unless there is a compelling reason not to.

"This change will get the projects completed quicker," says Sorrell, "help us give citizens more specific information on when the projects will be completed, and emphasize better planning on the contractors' part."

Cost-Estimating Challenge

The Springfield Interchange work was the most recognized of the projects that were underestimated in terms of cost. VDOT engineers now agree that, over the years, projects were added to Virginia's Six-Year Improvement Program, the agency's blueprint for distributing anticipated funds to transportation projects, with unsound cost estimates developed early in the projects' lives. This underestimating led to public and political criticism because, year after year, costs in the program document would increase, sometimes dramatically.

Bill Cannell, formerly a VDOT public affairs manager for Virginia's huge Hampton Roads urban area recalls, "It was very difficult to explain to a savvy reporter who had covered VDOT for years why a project's cost estimate increased 50 percent from 1 year to the next."

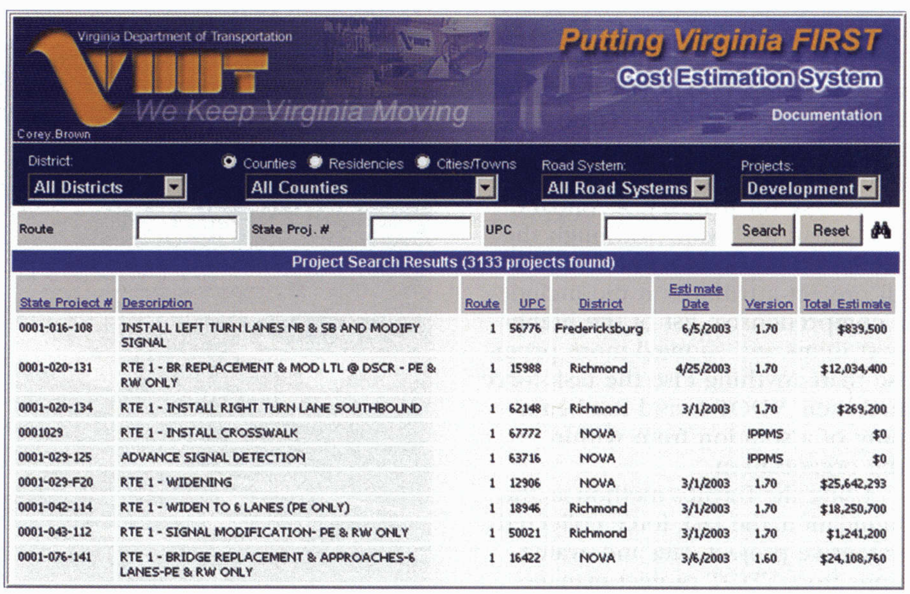
A month after starting Dashboard, Shucet tackled another major problem. VDOT did not have enough money for the construction projects in its Six-Year Improvement Program pipeline. In a sample of projects statewide, the difference between early project estimates and the final costs was more than 200 percent.

"In the newspapers, it seemed that you didn't see the phrase 'VDOT project' without the term 'over budget' lurking nearby," says Stephen Haynes, a VDOT engineer.

The problem was not unique to VDOT. An AASHTO Task Force on Project Oversight found that many State DOTs across the country have struggled with keeping their statewide transportation improvement programs in line with available funding. Some, such as Utah, dramatically changed their programming to make it more realistic, says Tom Stephens, P.E., now-retired director of the Nevada DOT and chair of the task force. Accurate, consistent, well-timed cost estimating has become such a challenge for many States that, in addition to the Project Oversight Task Force, AASHTO's Standing Committee on Highways Subcommittee on Design has formed a Cost Estimating Task Force to come up with solutions.

In VDOT's case, Virginia reduced the allocations in its program in 2002 by nearly a third from the previous year. Many early project cost estimates included too much guesswork and were far off the mark, usually on the low side. Many estimates were based on employees' judgment, expertise, and experience rather than a sound, consistent, methodological approach. The estimates often were created at differing points in a project cycle or in differing ways. Inflation was rarely factored in. Certain environmental treatments and unusual construction cost items were not always considered early in the projects' development, which resulted in costly work orders when those items came up after construction began.

VDOT needed a method for accurately estimating project costs early



State Project #	Description	Route	UPC	District	Estimate Date	Version	Total Estimate
0001-016-108	INSTALL LEFT TURN LANES NB & SB AND MODIFY SIGNAL	1	56776	Fredericksburg	6/5/2003	1.70	$839,500
0001-020-131	RTE 1 - BR REPLACEMENT & MOD LTL @ DSCR - PE & RW ONLY	1	15988	Richmond	4/25/2003	1.70	$12,034,400
0001-020-134	RTE 1 - INSTALL RIGHT TURN LANE SOUTHBOUND	1	62148	Richmond	3/1/2003	1.70	$269,200
0001029	RTE 1 - INSTALL CROSSWALK	1	67772	NOVA		!PPMS	$0
0001-029-125	ADVANCE SIGNAL DETECTION	1	63716	NOVA		!PPMS	$0
0001-029-F20	RTE 1 - WIDENING	1	12906	NOVA	3/1/2003	1.70	$25,642,293
0001-042-114	RTE 1 - WIDEN TO 6 LANES (PE ONLY)	1	18946	Richmond	3/1/2003	1.70	$18,250,700
0001-043-112	RTE 1 - SIGNAL MODIFICATION- PE & RW ONLY	1	50021	Richmond	3/1/2003	1.70	$1,241,200
0001-076-141	RTE 1 - BRIDGE REPLACEMENT & APPROACHES-6 LANES-PE & RW ONLY	1	16422	NOVA	3/6/2003	1.60	$24,108,760

The Cost Estimation System's Intranet opening screen lists the most essential details for thousands of projects. From this screen, users can click down to more detailed pages.

on that considered the many different factors that can change costs. The method had to be something that VDOT's nine districts would use uniformly in a State where the topography ranges from beaches and swamps to mountains and valleys. And it had to be user-friendly.

Commissioner Shucet tasked Allen to lead an effort to develop a definitive, consistent, well-documented approach for estimating construction projects. A task force that included VDOT engineers and researchers, two Commonwealth Transportation Board members, and a metropolitan planning organization member either had to locate the best available early project estimating system or develop one.

Through research, the task force found that many State DOTs were attempting to address the problem, but none had a "silver bullet." Washington State DOT was using a range of estimates for risk factors. California's transportation agency, Caltrans, was using three estimates: optimistic, pessimistic, and realistic. Although these approaches had merit, the task group did not think that they would help VDOT.

The method with the most potential revealed itself in VDOT's own backyard. Haynes, a member of the task force, had developed a project scoping estimation method 3 years earlier. The method, a feature-based system using Microsoft® Excel software, was estimating the district's road costs accurately using historical data. Estimation errors were lower in his district than the statewide average. The Haynes method included an annually compounded inflation factor. It was applicable for primary, secondary, and urban highways. Although the method did not take into account all project attributes, it did include a comprehensive list of the higher cost items and showed more promise than anything else the task force had seen. VDOT found the beginning of a solution from within the organization.

Using the Haynes method as the foundation, the task force collected extensive project data and evaluations from VDOT project management staff to build a project information center that includes:

- A structured scoping system to provide early and complete input
- An estimating system that is thorough and simple to use
- A Web-based database serving as a project information repository

Scoping and Estimating

"We learned early on that an incomplete or inaccurate estimate in the early life of a project was only going to get worse by the time we were ready to advertise it," says task force member Harry Lee, Fredericksburg District location and design engineer and Haynes' boss. "We had to develop some methods for 'doing it right' on the front end—at the scoping stage."

VDOT had no consistent, uniform method to define a project's need, or how it could best be built—and by whom. This led to serious scope creep during the life of a project, so estimates did not hold up over time. The scope and the cost crept, yet often the original estimate was never adjusted to allow for those changes.

For uniformity and accuracy in the scoping process, part of the solution was to migrate all projects to a Web-based Intranet site that includes the project description, purpose, need, project narrative, team structure, schedule, basic project information, cost estimates, project tracking, documentation, approvals, and other details about the project. Each element is essential to the success of the estimating system. Each project has a site that serves as a repository for all information about that project—and only that project, Lee says.

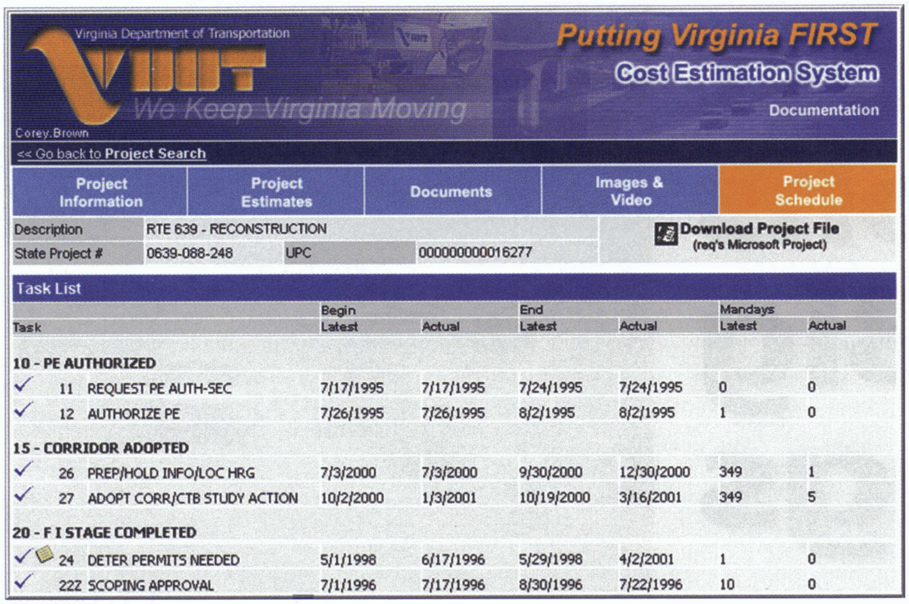
"We call it the Cost Estimation System, but it is 10 times more than that," says Mike Branscome, assistant location and design engineer in VDOT's Staunton District. "It's a project information clearinghouse. Our contract administrators love it because they can go to one place, and within 10 clicks or 60 seconds, they can get all the details they need without having to run reports." The district's preliminary engineering staff uses the system for project information to help prepare for scoping meetings, he notes.

The estimating part of the system includes spreadsheets that prompt users to enter details that can affect project costs, helping ensure that nothing is overlooked. While considering the usual features—road length, lanes, curbs, gutters, and the like—the possibility of landscaping, lighting, retaining walls, hazmat removals, and wetland or cultural mitigation also is considered.

Other worksheets require details for estimating bridge costs, right-of-way transactions, and utility relocations. Costs associated with inflation, construction engineering and inspection, and preliminary engineering are computed automatically and added to the estimate for a total project cost.

Every spreadsheet component must be completed, which requires

Virginia's new cost-estimating tool requires estimators to consider nonroutine items, such as bikeways like this one, when developing early project estimates.



Task		Begin Latest	Begin Actual	End Latest	End Actual	Mandays Latest	Mandays Actual
10 - PE AUTHORIZED							
11	REQUEST PE AUTH-SEC	7/17/1995	7/17/1995	7/24/1995	7/24/1995	0	0
12	AUTHORIZE PE	7/26/1995	7/26/1995	8/2/1995	8/2/1995	1	0
15 - CORRIDOR ADOPTED							
26	PREP/HOLD INFO/LOC HRG	7/3/2000	7/3/2000	9/30/2000	12/30/2000	349	1
27	ADOPT CORR/CTB STUDY ACTION	10/2/2000	1/3/2001	10/19/2000	3/16/2001	349	5
20 - F I STAGE COMPLETED							
24	DETER PERMITS NEEDED	5/1/1998	6/17/1996	5/29/1998	4/2/2001	1	0
22Z	SCOPING APPROVAL	7/1/1996	7/17/1996	8/30/1996	7/22/1996	10	0

The Cost Estimation System's project schedule screen outlines all the task milestones in a project's development and quickly shows what has been completed.

collaboration among staff members representing all aspects of a project, from the local office to VDOT's central office. Although Virginia's diverse geography can create variations in project costs across the Commonwealth, the system accounts for the variations by using district-specific adjusters. A 3 percent interest rate is factored into the estimates.

"Communications is the key here," says Lee. "And everyone has to do their homework on the project before that communication can happen. Much more work will be done prior to the scoping meeting than ever before, which should save significant time and money later in a project's development."

The goal is for estimates to be as close as possible to the final project cost. Applied to projects within VDOT's current Six-Year Improvement Program, the system is helping create a more realistic, credible, achievable program than in the past.

And how is it working so far? Early analysis of the system's performance indicates that cost estimates tend to be much closer to final project costs than ever before.

"The foundation of our business is getting the estimate right," says John H. Neal, Jr., VDOT's Hampton Roads District construction engineer. "Now we have one official source to go to for cost information. It's pretty explicit about what went into the estimate. It's producing realistic estimates."

Richard Caywood, P.E., VDOT's Petersburg resident engineer, adds, "It's given us a repeatable process framework that will increase our estimating precision every time we use it. It's taken something that was an art and made it into a science."

Next Steps

Dashboard's technical team plans to add several improvements before the system's first anniversary. Users will have a better picture of the projects—literally. A "Map It" feature will provide a geographic information system (GIS) map of the project area, "Picture It" will supply aerial photos of the project site, and "Drive It" will create a virtual drive of the project.

The Cost Estimation System will include major revisions to the right-of-way and utilities worksheets, details to address additional lanes and varying terrains, plus statewide training on using the system. A preliminary engineering tracking system module lets users tailor inquiries about schedules and budgets spanning the life of the projects.

A new plan sheet module to enable users to view and print design plan sheets—a time-saving feature—soon will be added. The agency also has plans to integrate the project documentation feature (for videos, photographs, e-mails, memos, and the like) with VDOT's Falcon, a repository for road designs and other project documentation.

Is all the hard work paying off? It appears so.

"Your technology linking independent databases and allowing public access and oversight through that technology is the best financial watchdog ever created," wrote Virginia's Deputy Secretary of Transportation Pierce Homer, in a memo to employees involved with Dashboard and the new Six-Year Improvement Program. "It simply will not be possible to create a $10 billion plan with only $7 billion of revenues. While I admire the technical elegance of these efforts, I admire even more their impact on responsible, democratic governance."

Shucet adds, "Dashboard and the Cost Estimation System changed our problems into opportunities to build on. With these tools, we will never go back to the way we did business before them. We owe it to ourselves and to our customers to only go forward—and to do it openly."

Finally, in their efforts to be good stewards of taxpayer investment in transportation, VDOT would like to offer other State and local transportation agencies the opportunity to use and adapt their project management and cost-estimating systems to their own agencies.

Donna Purcell Mayes is an assistant public affairs director for VDOT, a position she has held since 1990. She joined the agency as an editorial assistant in 1977. She is a member of the Public Relations Society of America and the Virginia Government Communicators.

For more information on Dashboard, contact Connie Sorrell, chief of Policy and Organizational Development, VDOT, connie.sorrell@virginiadot.org, 804-786-1476. For the Cost Estimation System, contact Gary R. Allen, Ph.D., chief of Technology, Research, and Innovation, VDOT, gary.allen@virginiadot.org, 434-293-1938.

Low-Cost Solutions Yield Big Savings

by Ron Zeitz

Fatality rates on South Carolina's interstates were rising, but the transportation agency made dramatic improvements that save lives.

South Carolina, faced with a disturbing increase in traffic fatalities, decided to take strong action. But limited resources posed a possible hindrance to meaningful results. The challenge was daunting.

Ready to accept the challenge, the South Carolina Department of Transportation (SCDOT) and the South Carolina Division of the Federal Highway Administration (FHWA) expanded their partnership. "We decided to put our heads together and make safety our number one priority," says FHWA's South Carolina Division Administrator Bob Lee.

Since 1992, the State's fatalities had been rising 4 percent per year. In addition, the State has the Nation's fourth largest State-maintained highway system. In the face of a rising fatality rate and budget constraints, how would South Carolina be able to improve safety?

(Above) Based on a study of crash records and the conditions that caused median crossovers, SCDOT decided to install barriers on medians that are less than 18 meters (60 feet) wide. *Photo: South Carolina DOT.*

"Because we couldn't fix everything at once, we took a focused approach," says SCDOT Executive Director Elizabeth Mabry, "and decided to tackle the 1,336 kilometers (830 miles) of interstates as a prime target for fatality reduction."

"Fatalities [on those highways] increased from 89 in 1997 to 162 in 2000," Lee adds, "and because interstates are eligible for Federal aid, we knew we could allocate the funds for some measures that would bring down the fatality rate as quickly as possible."

Slowing Speeds

Mabry and Lee agreed that decreasing speed limits on the interstates where they enter urban areas would be the place to start as a low-cost, high-yield measure. Accordingly, SCDOT reduced urban speed limits in high-crash areas to 89 or 97 kph (55 or 60 mph)—a reduction of 8–16 kilometers per hour (5–10 miles per hour). SCDOT posted new signs and coordinated with the South Carolina Department of Public Safety and local law enforcement agencies.

"We knew it would be an unpopular decision," says SCDOT Executive Director Mabry, "but our public awareness efforts minimized complaints." The transportation agency also launched a massive public safety campaign that included nearly 7,000 "Highways or Dieways" broadcast commercials. In addition, the agency established a Web site (www.scdot.org) that ultimately received more than 2,000 hits each month.

The results speak for themselves. Since December 2000, urban interstate fatalities in South Carolina have dropped 54 percent as a result of the project.

Testing Truck Lane Restrictions

Other segments of the Interstate System still seemed to induce crashes, especially those involving commercial vehicles. In particular, Interstate 85, a major north-south route for heavy trucks, continued to have a number of crashes. National studies showed that lane restrictions potentially could lower the crash rate. When it became known that the State was considering such restrictions, the trucking industry expressed some concerns about safety and operations.

To allay industry concerns, FHWA and SCDOT implemented a pilot project to study lane restrictions. SCDOT established the restrictions temporarily for 1 year on two high-crash interstate segments. The South Carolina Department of Public Safety used targeted enforcement, both for lane violations and aggressive driving violations. The results of the lane restrictions were a 78 percent reduction in truck-related crashes. The outcome enabled FHWA, SCDOT, the SC Department of Public Safety, and the South Carolina Truckers Association to reach a consensus that restricting trucks to the two right travel lanes on three-lane sections would offer improvements in safety and traffic operations. Truck lane restrictions were expanded to 170 kilometers (106 miles) of interstates in the State.

Since the full implementation of truck lane restrictions in 2001, truck crashes on interstates in South Carolina have increased slightly, but fatalities involving heavy trucks have decreased.

Increased lane densities, increased speeds, and unprotected narrow median strips can combine to produce a far higher potential for head-on crashes.

Barrier Systems Compliant with NCHRP-350 Criteria

Three-Strand Cable
This system is considered the safest for motorists and also has the lowest initial installation cost. It can be installed with a single run near the center line of the median and can be used on slopes with a 6:1 ratio. It requires the highest level of maintenance.

W-Beam
This is the standard steel guardrail that requires a dual run for narrow median protection. It also must be installed on slopes 10:1 or flatter.

Box Beam
This is a tubular system that also requires a dual run for narrow median protection and a slope no steeper than 10:1.

Modified Three Beam
This steel guardrail requires a dual run for narrow median protection and a slope no steeper than 10:1.

Concrete Safety Shape
This is the most rigid of the median barrier systems and also the most costly, as it requires extensive grading, drainage, and paving. It also requires a slope no steeper than 10:1, but it is the system that requires the least maintenance.

The Message Is in The Median

Narrow, unprotected median sections were under the scrutiny of the two partner agencies. Median crossover crashes on interstates in South Carolina warranted special attention because of the devastating effects and multiple loss of lives almost always associated with this kind of incident. In 1999–2000, more than 70 people in South Carolina lost their lives in 57 separate interstate median crashes. Causes for median crossovers include inattention, fatigue, improper lane changes, medical emergencies, and equipment failure, among others.

Were these median crossover crashes occurring at a particular location or set of locations? To find the answer would require the analysis of some 3–5 years' worth of crash reports, numbering between 24,000 and 40,000. A cursory review of some of the fatality data indicated that these incidents were random in nature and did not appear to be isolated to specific locations.

A series of three median crossover crashes that killed 13 people in a 3-month period on one 16-kilometer (10-mile) stretch of highway raised doubts about this theory. The three incidents suggested that the narrower the median strip and the higher the traffic volumes, the greater the chances for a head-on collision. In addition, the length of the on- and off-ramps in this section, short by today's standards, appeared to contribute to frequent vehicle weaving conflicts. SCDOT and FHWA established priorities for correcting these dangerous situations, and determined top candidates for installation of barrier systems based on median widths of 11 meters (36 feet) or less. All traffic barrier systems used on the National Highway System must conform to the National Cooperative Highway Research Program (NCHRP) standard for crash barriers—NCHRP-350 criteria (NCHRP's *Recommended Procedures for the Safety Performance Evaluation of Highway Features, NR-350*). Although five types of crashworthy barrier systems are available (see "Barrier Systems Compliant with NCHRP-350 Criteria"), each has its advantages and disadvantages, and some would not be entirely satisfactory for South Carolina interstates.

The three-strand cable system was deemed most appropriate for installation as it is the safest for motorists, has the lowest initial cost, and can be installed in medians at least 7.3 meters (24 feet) wide and on 6:1 slopes (0.3 meter of incline for every 1.8 linear meters or 1 foot of incline for every 6 linear feet). The chief drawback is that the three-strand cable system requires a high level of maintenance. Each time it is struck, it collapses, making it necessary to rebuild after every crash. SCDOT estimated the project could cost $40 million.

In August 2000, Executive Director Mabry and Division Administrator

South Carolina DOT

To prevent distracting other drivers, crash vehicles like this one are removed from the scene of the incident as rapidly as possible—usually within 1 hour but often in less time.

Lee concluded that the study period was over, and it was time to act. They agreed to redirect construction funds and undertake a 5-year plan at $8 million per year, using 100 percent Federal-aid funds to install the cable barrier system on all prioritized medians. Because of the urgency of the program, the State Transportation Infrastructure Bank and other sources subsequently made additional funds available. Mabry accelerated the cable median barrier program, and the first contract was awarded in October 2000.

Through leadership and the dedication of additional resources, the contracts were completed on January 31, 2003, with the installation of 506 kilometers (314.5 miles) of three-strand median cable at a considerably reduced cost of $18.5 million on all interstate segments with medians less than 18 meters (60 feet) wide. In other words, the 5-year program was finished in about 2 years and significantly under budget.

As the program progressed, it became evident that the number of median incursions was far higher than was anticipated originally. The system was averaging more than three "hits" per mile per year. Through July 2003, the system sustained more than 3,000 hits. But more surprising than the number of hits was the number of "saves." Only 15 vehicles—less than 1 percent of those that hit the median barrier—penetrated the cable system, resulting in 8 median crossover fatalities.

To ensure that damaged cable was repaired rapidly and returned to service, the contracts stipulated that the contractor restore the damaged section completely within 96 hours of notification. A statewide contract now provides for maintenance of the cable system to ensure continued effectiveness. Repair costs now average approximately $1,000 per hit.

Significantly, most of the penetrations involved vehicles operating outside the restraining capabilities of the specifications in NCHRP-350, involving high speeds or hitting the barrier at angles greater than 25 degrees. Heavy trucks exceeding the system's stopping capabilities also accounted for penetrations.

Early in the program, rural emergency service providers and local law enforcement agencies expressed concerns about their need for U-turns across the median in some rural areas. The transportation partnership assembled an inclusive team to evaluate the need and make a recommendation. The team concluded that median openings should be provided for emergency turnarounds at 8-kilometer (5-mile) intervals, according to AASHTO guidelines. The openings have improved surfaces, but motorists are deterred from crossings by flexible barriers.

Of Repairs and RUSH

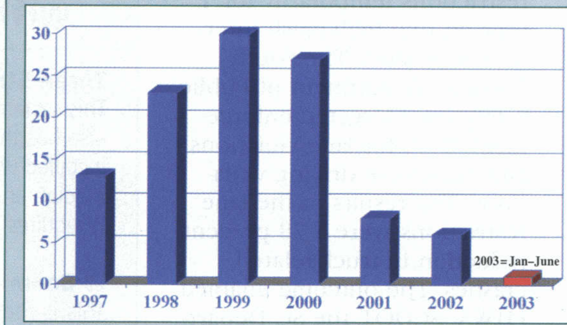
One other area that received the partnership's attention was the interstate on- and off-ramps, many of which were now unsafe by today's standards and traffic volumes because of their lengths or locations. "At $20 million to $30 million to reconstruct just one typical interchange," Lee says, "we would never be able to catch up and improve safety and operations systemwide."

The partnership identified some 20 interchanges for low-cost safety improvements totaling $10 million, and the program was given a name, Ramp Upgrades for Safer Highways, or RUSH for short. The transportation agency launched the program with a pilot project and evaluated the results before initiating the full-fledged program.

South Carolina DOT

Repair crews are on the scene 48 hours or less after a median incursion is reported. Repairing the barrier usually takes 1 hour or less and requires no lane closings during the repair. Here a crew is using a portable pole driver to install a new pole.

Fatal Crashes Caused by Crossing over Interstate Medians



Source: South Carolina DOT

The chart shows that fatal crashes were rising before SCDOT instituted its multifaceted program to improve safety. Following installation of the cable barrier system, the number of fatal crashes dropped dramatically.

Most of the projects were completed in 2002, and new projects are under development.

Doing More with Less

"Being in the five top States in highway fatalities for over a decade is not an envious place to be," says Lee. "Through thoughtful planning, partnering, public awareness, and a focus on results, SCDOT and FHWA have curbed the increase in fatalities in South Carolina since 1999, in spite of very limited resources," Mabry says. "We are pleased to have reduced interstate fatalities 36 percent in just 2 years."

Lee adds, "Each of the initiatives discussed here met some opposition. Motorists don't appreciate reduced speed limits, truckers don't want lane restrictions, and local law enforcement and emergency responders questioned the loss of total access to interstate medians. Not one of these initiatives would have moved forward but for the leadership and genuine commitment to improving highway safety exemplified by Elizabeth Mabry, executive director at SCDOT and my partner."

Ron Zeitz is a senior editorial consultant in FHWA's Public Affairs office in Washington, DC. His career spans more than 30 years in public relations, much of it in the private sector, working for high-tech companies. He is the former editor of *The FHWA News*, FHWA's publication for its employees and retirees.

Improving Bridge Inspections

by Glenn A. Washer

Researchers at FHWA are developing innovative nondestructive evaluation technologies to assess the condition of bridges.

Shortly after the collapse of the Silver Bridge between Point Pleasant, WV, and Gallipolis, OH, in 1967, the Federal Highway Administration (FHWA) developed the National Bridge Inspection Standards to provide guidance on inspecting bridges for safety. The standards require the inspection of all bridges on public roadways in the United States on a periodic basis, normally at least once every 2 years. FHWA maintains the data from the inspections in the National Bridge Inventory, a database of information on the size, construction, and condition of bridges and culverts in the United States.

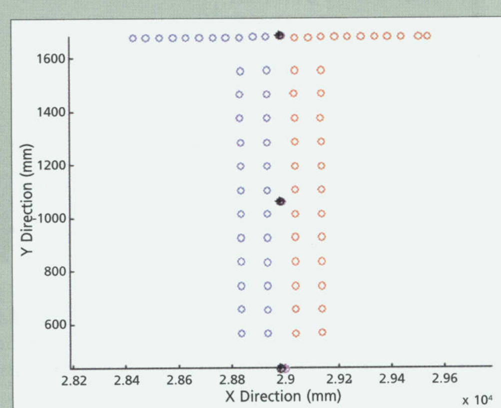
For more than 30 years, inspectors relied largely on visual inspections to evaluate the condition of bridges. Although some State departments of transportation (DOTs) have employed nondestructive evaluation (NDE) methods to complement visual inspection, widespread use of NDE technologies has been limited. New NDE technologies increasingly are sought to solve difficult inspection challenges that are beyond the capability of normal visual inspections.

The Nondestructive Evaluation Validation Center (NDEVC) at the FHWA Turner-Fairbank Highway Research Center in McLean, VA, is developing new and improved technologies to meet these needs. Recent activities at the NDEVC include research on the reliability of routine inspection methods and the development of innovative nondestructive evaluation tools. Current focus areas include laser measurement technologies, bridge deck inspections, monitoring systems, inspection of composites, automated ultrasonic testing, reactive powder concrete testing, and NDE for post-tensioned bridges.

Validation Center

In 1996, the U.S. Congress mandated that FHWA develop a center for evaluating NDE technologies. FHWA designed the NDEVC to provide State highway agencies with independent development, evaluation, and validation of nondestructive evaluation technologies. The center also researches new technologies to

Laser measurement (below) helped locate predrilled bolt holes in these steel girders (left) and determine hole locations for fabricating a splice plate to join the girders.



solve specific problems related to inspecting and evaluating bridges.

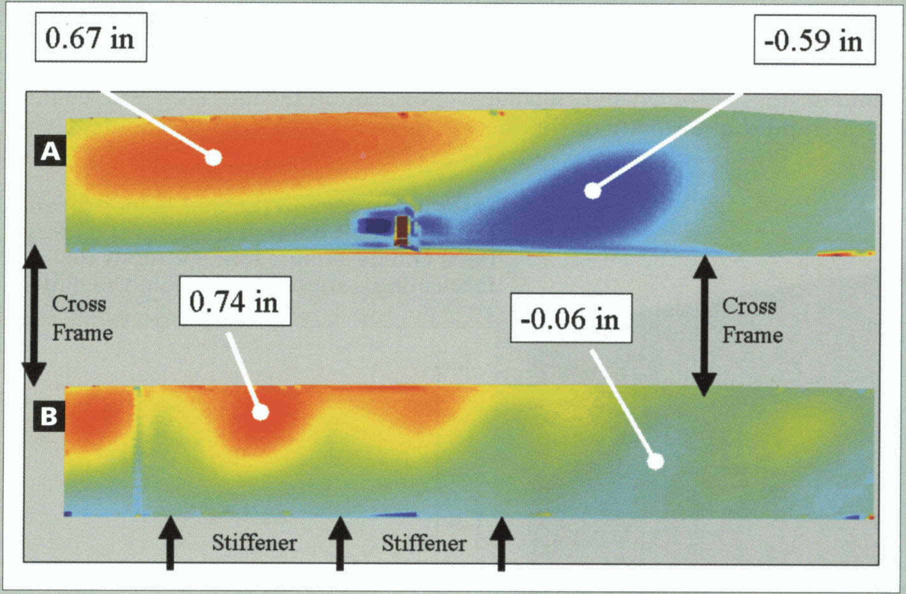
The validation center includes a laboratory, test bridges, and component specimens. The laboratory serves as the nucleus for preliminary testing and evaluation. Test bridges in northern Virginia and Pennsylvania provide sites for practical trials that evaluate technologies under realistic field conditions. The center also uses sections of bridges containing defects, known as *component specimens*, to perform capability trials in the laboratory and conduct research related to developing new technologies.

Reliability of Visual Inspection

The National Bridge Inspection Standards require that inspectors periodically inspect the Nation's bridges and report bridge conditions in a standardized format. Condition ratings range from zero to nine for each of three bridge components: the superstructure, substructure, and deck. By assigning condition ratings to each component, the standards help FHWA measure bridge performance at the national level, forecast future funding needs, determine the distribution of funds among States, and assess the maintenance needs for a particular structure. The accuracy of the ratings is important to identifying bridges in need of maintenance and repair and ensuring that FHWA programs for funding construction and renovation are equitable and meet the FHWA goal of reducing the number of deficient bridges.

In 1998, the NDEVC initiated research on the accuracy of the bridge inspection process. The study provides overall measures of the reliability and accuracy of inspections, identifies factors that may influence the results, and determines procedural differences between State inspection programs. Completed in June 2001, the research report, *Reliability of Visual Inspection for Highway Bridges, Volume I: Final Report (FHWA-RD-01-020)*, is available online at www.tfhrc.gov/hnr20/nde/01020.htm.

The study asked 49 practicing bridge inspectors from across the United States to examine the test bridges in Virginia and Pennsylvania associated with the NDEVC. Each inspector performed 10 separate tasks, including routine and indepth inspections. They used common hand tools such as a masonry hammer, plumb bob, carpenter's level, binoculars, and other nonintrusive tools. An NDEVC observer documented the performance and behavior of the inspectors during the inspection tasks.



This figure illustrates laser deformation data on a 1- by 6-meter (3- by 20-foot) section of a curved girder web under loading. (A) shows the distortion of a web without stiffeners; (B) shows distortions of a web with vertical stiffeners at the locations indicated.

During the routine inspections, the NDEVC staff asked the inspectors to provide a condition rating for the superstructure, substructure, and deck. The study revealed a wide distribution of condition ratings reported by inspectors evaluating the same bridge sections. On average, they assigned between four and five condition ratings for each separate component. For some components, inspectors provided as few as three different condition ratings; for others, inspectors provided as many as six. The average was between four and five.

Statistically, if the results were extrapolated to the entire population of bridge inspectors, the results indicate that only 68 percent of the reported condition ratings for these elements would vary between plus or minus (+/-) 1 from the average rating for a particular element. This data and other data from the study indicate a wide variation in the manner in which inspectors conduct routine inspections. The study concluded that the definitions of particular condition states may not be refined enough to facilitate accurate and reliable ratings.

In addition, the inspectors performed two indepth inspections, defined as up-close, arms-length inspections generally conducted to identify deficiencies not normally detected during routine inspections. One indepth inspection involved evaluating a welded steel girder with fatigue-sensitive details. The inspectors were expected to search for and find seven crack indications on a specific portion of a steel bridge. Inspectors reported the crack indications at a rate of 3.9 percent. About 4 out of every 100 inspections of a particular crack indication correctly identified the indication. Test results indicated that 86 percent of the inspectors who correctly identified the indications used a flashlight for the inspection and were on average 0.2 meter (0.7 foot) from the girder during the inspection. Among inspectors who did not correctly identify indications, only 38 percent used a flashlight, and the inspectors averaged 2.7 meters (8.9 feet) from the girder during the inspection.

These results indicate that the low crack-detection rates found during the study may be related to how the inspections are performed, and additional training or retraining may increase the use of appropriate inspection practices. It was concluded that a significant portion of indepth inspections are unlikely to note defects beyond those found during a routine inspection.

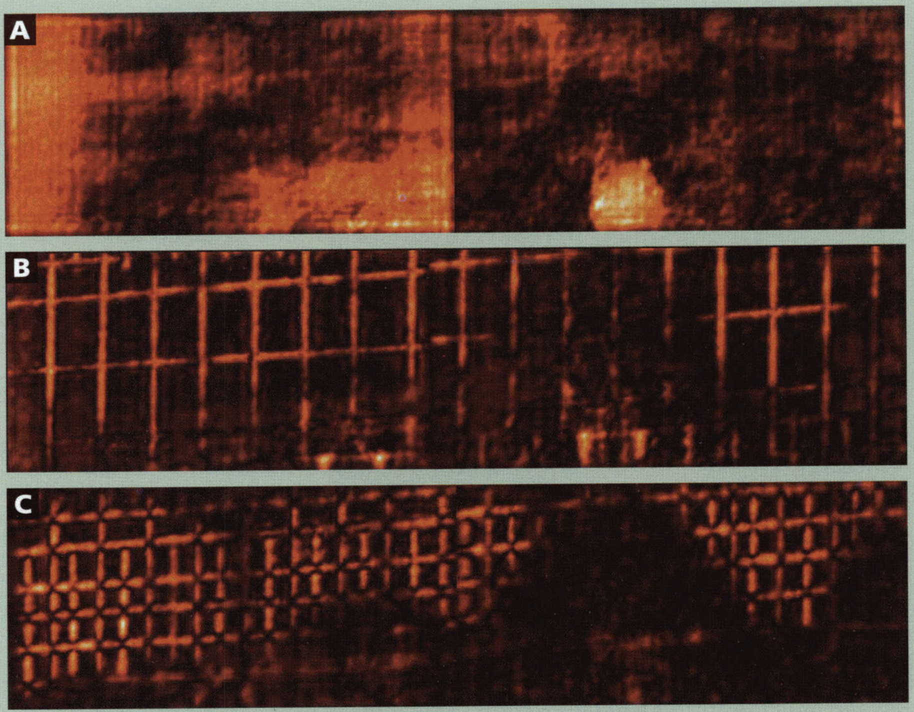
Laser Measurement Technologies

Over the last 7 years, the NDEVC has developed numerous applications using laser-based distance measurements for highway infrastructure. A scanning laser system was developed as part of an FHWA research and development program. The system can measure distances with submillimeter accuracy over a range of 30 meters (98 feet). The mechanized scanning head enables the laser to scan over +/- 200 degrees on one axis and +/- 60 degrees on a second axis. Two angles and the distance measurement combine to locate a point in three-dimensional space; targets are not required.

Applications for this technology include measuring bridge deflections under calibrated load to evaluate structural behavior, calculating out-of-plane distortions in girder webs and flanges, and evaluating the as-built construction of large structures such as abutments.

This unique measurement technology recently has been applied to the fabrication of steel bridges. For many bridge construction projects, fabricators are required to set girder sections at their final elevations at the shop, prior to shipping to the job site. This ensures that bolt holes in splice plates align properly when workers construct the bridge in the field. The cost of assembling the entire bridge at the fabrication shop can be extremely high, adding between 5 and 15 percent to the project cost.

Proof-of-concept testing has been conducted using the laser system to measure the precise location of bolt holes in bridge girders following fabrication. The girders are then virtually assembled in the computer to determine the exact location of holes in splice plates that will be used to join the girders. In this manner, the bridge can be constructed virtually using laser-based measurements, eliminating the need to assemble the bridge at the fabrication shop.



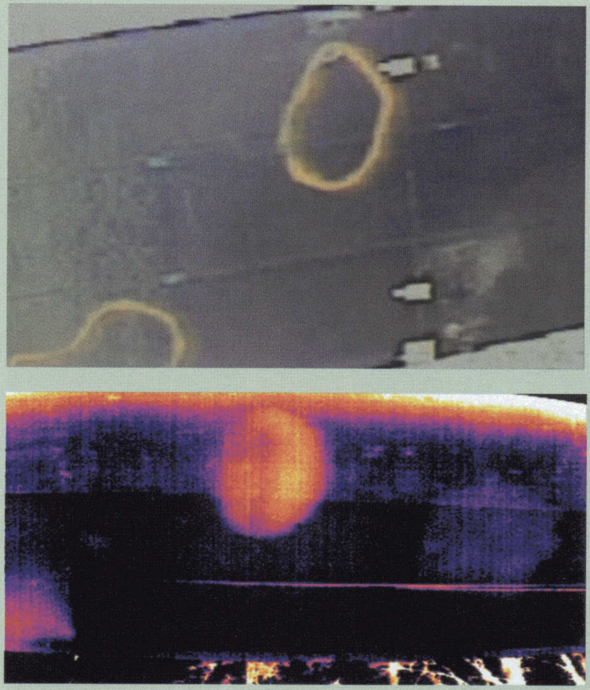
During field testing, the new HERMES GPR technology captured images of a delamination in a concrete bridge deck approximately 0.8 by 3 meters (2.6 feet by 9.8 feet). A GPR image of the top surface (A) shows a concrete patch in the deck, indicated by a bright circular feature in the lower right of the image. In the top mesh (B), rebars appear as bright grid-like lines except where delaminated concrete causes a loss of contrast in the image. An image of the bottom mesh (C) again shows the rebar pattern and the concrete delamination, which appears as an occluded portion of the image.

Another recent application of the laser measurement technology is measuring out-of-place web distortions in a curved-girder bridge. Laser technology offers several advantages for this application. First, distortions of the web over a large field can be determined from a single measurement location. Second, no interaction with the beam under test is required because the measurements are noncontact and made at a range of up to 30 meters (98 feet), although typically at 10 to 20 meters (20 to 60 feet). The resulting images of the out-of-plane distortions of the web can be used to quantify the effects of attachments on beam performance, identify local buckling phenomena, and track beam behavior during testing.

Bridge Deck Inspections

The National Bridge Inventory indicates that there are more than 298 million square meters (3.2 billion square feet) of bridge deck in the United States. Most decks are made of reinforced concrete that provides the driving surface for the bridge. The service life of a deck can be much shorter than that of the substructure and superstructure. Decks deteriorate due to corrosion of the reinforcing steel, and the resulting delaminations and spalling can make a deck structurally deficient. Detecting deterioration in its early stages is critical to helping State DOTs repair the most at-risk bridges and optimizing the use of limited funds.

To meet that need, FHWA is developing ground-penetrating radar (GPR) systems for detecting and imaging subsurface defects in concrete bridge decks. Several prototype systems have been developed under a project known as the High-Speed Electromagnetic Roadway Measurement and Evaluation System (HERMES). The goal of the project is to develop a GPR system that can image deterioration in concrete bridge decks accurately while traveling at highway speeds. Imaging is conducted by an array of GPR antennas that operate in a synchronized manner, such that detailed images can be produced from GPR data.



Researchers identified a delamination (circled in the video image, top) in a carbon-fiber composite using a tap test and infrared imaging (bottom).

Recent project efforts have focused on developing new, higher-frequency antennas to provide improved imaging resolution when integrated into the array architecture. A pooled fund study with 19 participating States has funded the development of a single antenna prototype that uses a robotic cart to scan over a bridge deck to simulate performance of the larger multichannel array. The new antenna has significantly higher bandwidth than previous antenna designs, and field testing has shown significant improvement in the system's ability to image deck deterioration. Ongoing testing is exploring the improved imaging capabilities of the antenna under a wide range of test conditions in the field and examining the ability of the system to image defects in asphalt and concrete pavements.

Bridge Monitoring Systems

The NDEVC is involved in developing various instruments to monitor the performance of civil infrastructure. Generally, these instruments are dedicated, remote data-acquisition systems that collect information on the behavior of a structure over time. They log data in a system memory that can be downloaded periodically. Designed to be inexpensive, rugged, and battery-operated, the systems operate on a flexible platform that can be customized for particular applications and installed quickly in the field.

Several systems have been assembled for various applications. Transducers, for example, can monitor the displacement of a wing-wall relative to the abutment, using an eddy-current sensor. Designed at the NDEVC, the sensor measures the relative movement and tilt of the wing-wall, providing a stable measurement of displacement over long periods of time with minimal power consumption. As of November 2003, the system had been in place for 38 months on a bridge in Washington, DC.

Inspection of Composite Structures

The growing use of composites in civil infrastructure presents many challenges in terms of post-construction inspection for quality control and monitoring of the long-term performance of materials. To address these challenges, the NDEVC is developing thermographic methods for evaluating composite bridges and composite bridge repairs.

Thermographic systems operated under ambient weather conditions are used to detect anomalies in heat transfer that occur due to delaminated or debonded material. Applications include detecting delaminations in a carbon-fiber laminate used to strengthen concrete bridges and debonding of epoxy overlays in composite bridges. The data are collected under ambient environmental conditions without the use of external heat sources. Diurnal (daily) temperature variations and the significantly different thermal conduction properties of the overlay and the substrate material provide the thermal gradients necessary to create thermal contrasts at defects. The technique, known as passive infrared thermography, enables fast scanning of structures and reduces the need to access structures at close distances to apply active heating.

Automated Ultrasonic Testing

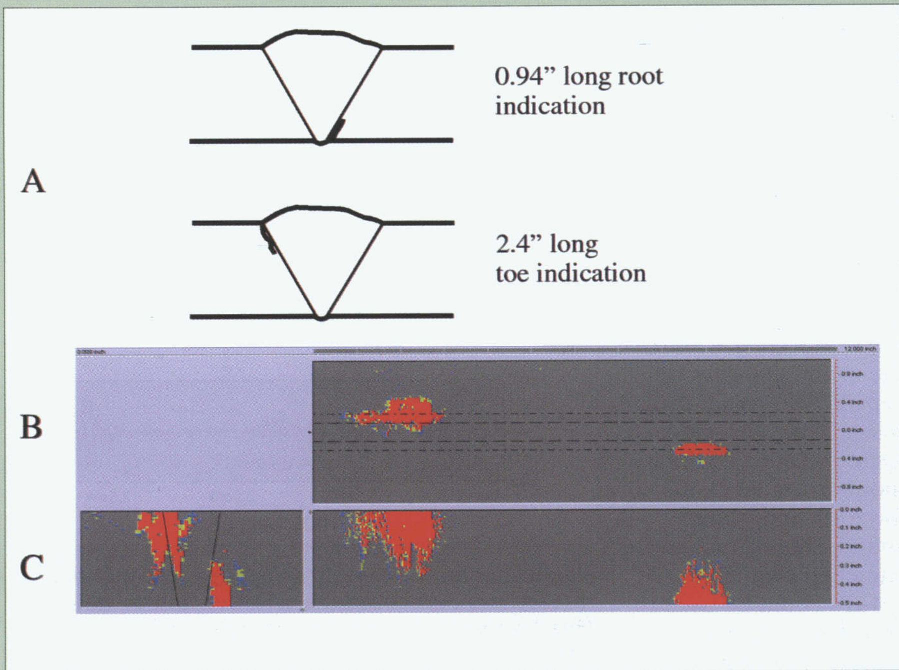
Automated ultrasonic testing (AUT) combines traditional ultrasonic testing methods with computerized data acquisition and processing. AUT technologies have been available for several years, and inspectors increasingly use these methods during routine inspections of pipelines and in aeronautical applications.

AUT offers several advantages over traditional ultrasonic testing techniques:

- Images created by an AUT system can be easier to interpret, especially in areas with complex geometries.
- AUT systems preserve a record that inspectors can use to confirm the completeness of inspections and archive for future use.
- AUT systems can be combined with robotic scanning systems to provide efficient and repeatable inspections of standard weld geometries.

Both ultrasonic and radiographic testing are used to inspect steel bridges during fabrication to ensure weld quality. Radiographic testing is more common for steel bridges in the United States than ultrasonic testing, although requirements vary by State and bridge member design. Because radiographic testing is a well-proven method that provides a more complete record than manual ultrasonic testing, bridges owners frequently prefer it. The health issues related to radiographic testing, however, introduce logistical difficulties in the fabrication process that result in increased costs. AUT, on the other hand, provides a more complete record than manual UT and may represent a safer alternative to radiographic testing.

In 2002, the NDEVC began developing and evaluating AUT systems to inspect steel bridges during fabrication. The goal was to determine if AUT technology can provide an alternative to radiographic testing as a quality-control tool. The study examined the use of AUT technology for inspecting butt-welds and com-



Internal defects in welds, such as the cracks shown in (A) can be detected and imaged using AUT systems. The plan-view acoustic image in (B) shows the crack indication with dashed lines superimposed to indicate the geometry of the plate bevels prior to welding. An elevation view of the acoustic data (C) shows the crack depths. As these images illustrate, automated ultrasonic testing reveals both the indication amplitude and dimension (length) of the defect, providing key information for classifying defects.

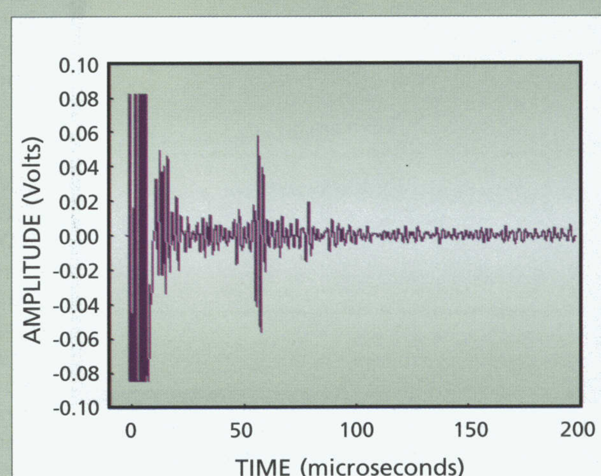
pared the results with those using radiographic testing.

To date, researchers have conducted more than 150 hours of in-line testing at fabrication shops, in parallel with industrial radiographic services. Results indicate that AUT can be an effective inspection tool that could be used in place of radiography under certain conditions. A final report detailing the testing conducted during this study should be available in 2004.

Reactive Powder Concrete Testing

A new class of concrete known as reactive powder concrete (RPC) is becoming available in the United States for fabricating bridge members. Classified as ultrahigh performance concrete, the material consists of sand as its largest aggregate and fine steel fibers distributed within the concrete itself. RPC achieves compressive strengths of up to 200 megapascals, MPa (29 kips per square inch, ksi), compared with maximum compressive strengths of 50 to 100 MPa (7 to 15 ksi) for high-performance concretes. Young's modulus values greater than 50 gigapascals (7,000 ksi) are common for RPC. Obviously civil engineers would be very interested in an easily formable material with high compressive strength and stiffness, but introducing this new material brings new challenges for nondestructive evaluation. Applying RPC in the field will result in lighter sections, longer spans, and innovative new section geometries. Effective tools to assess bridge condition will play an important role in integrating this new material into the civil engineering community.

Because of the homogeneous, highly packed nature of the RPC microstructure, it is possible to use ultrasonic testing methods for inspection and materials characterization in ways not possible with traditional concrete. Transducer frequencies of 10 to 20 times those used in normal concrete can be used to launch and receive ultrasonic waves over distances on the order of several hundred millimeters. Initial research indicates that ultrasonic wave velocities can help determine the elastic properties of the material, and traditional pulse-echo ultrasonic testing can be used to detect cracks in the cement matrix. Ongoing research is exploring how ultrasonic velocity measurements can be used as a quality-control tool during construction and how ultrasonic testing may be used for in-service inspection of bridges constructed of RPC.



Typical ultrasonic signal from a crack in an RPC specimen.

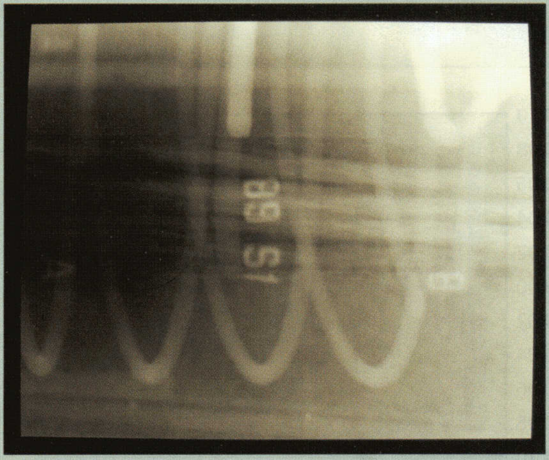
Post-Tensioned Bridges

Steel tendons that provide compressive forces on post-tensioned concrete bridges are critical structural elements. The forces provided by these tendons counteract tensile forces that result from the substantial dead weight of the structure and traffic loading. The construction elements that use post-tensioned tendons include segmental and cast-in-place concrete bridges, integral pier caps, substructures, and piers.

Steel tendons typically are located inside metal ducts within the concrete member. Workers fill the ducts with a cementitious grout that protects the corrosion-sensitive, highly stressed tendons. The grout is intended to fill the duct completely so water cannot collect there, and the highly alkaline environment created by the grout around the tendon inhibits corrosion.

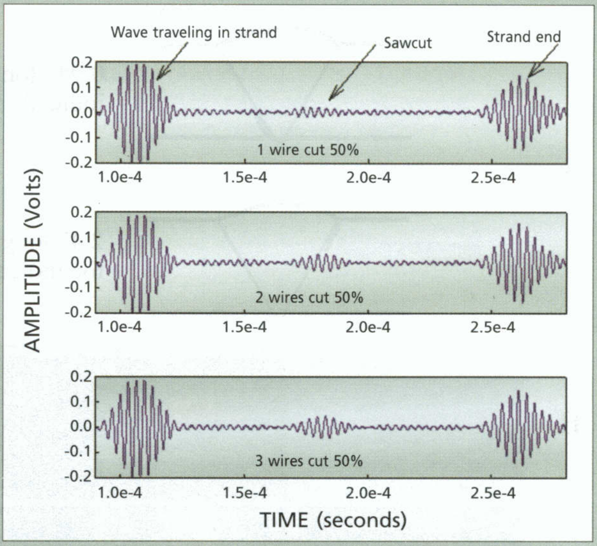
Substantial evidence in Europe and the United States indicates that tendons may be susceptible to failure due to corrosion at locations where the duct has not been grouted properly. Improper grouting may result in a void or pocket around the tendon where water can collect, creating a corrosive environment. Since the tendons are located within the concrete, they represent a significant challenge for inspectors. The most widely used approach to finding and evaluating voids is to excavate the concrete to expose the tendon, open the duct, and examine the strands. This process, however, is destructive and provides only intermittent results since it is impractical to expose the entire duct.

As an alternative to excavation, FHWA is examining the effectiveness of using high-powered linear accelerators to radiograph the internal features at duct locations. Portable linear accelerators that have energies of 6 megaelectron volts are available from service providers. NDEVC staff conducted laboratory experiments using this technology, and the Central Artery Tunnel Project in Boston, MA, and the Florida Department of Transportation have used the technology in field experiments. Although studies indicate that radiographic testing can detect broken strands and voids in the grout under field conditions, the technology remains cumbersome to apply and expensive. Future efforts at FHWA may include developing a system engineered for application to civil infrastructure.



A high-energy radiograph of the anchorage area in a post-tensioned concrete bridge shows individual strands (running left to right), reinforcing steel spiral (encircling the duct), and the duct itself.

Ultrasonic methods to monitor tendon condition are another approach to examining post-tensioning systems. FHWA developed electromagnetic acoustic transducers (EMATs) that encircle individual strands. EMATs launch and receive acoustic waves traveling within the strand and may be capable of serving dual roles. First, acoustoelastic methods could monitor the level of force carried in the strand. Second, waves launched from the EMATs could be used to detect broken wires within the strand. EMAT sensors embedded in a structure during the construction process could monitor the condition of the system over the life of the bridge. Proof-of-concept testing is ongoing at FHWA.



Electromagnetic acoustic transducers could help researchers detect broken wires within a strand. This figure shows sawcuts detected in a seven-wire strand with one wire cut 50 percent, two wires cut 50 percent, and three wires cut 50 percent. Sensors embedded in a structure during the construction process could help bridge owners monitor the condition of the system over the life of the bridge.

Safety Is the Goal

The goal of the Nondestructive Evaluation Validation Center at FHWA is to improve the state of the practice for highway bridge inspection. Staffed with a multidisciplinary team, the facility will continue to evaluate the reliability and accuracy of existing NDE technologies and work to develop new ones. By improving tools for inspecting and evaluating bridges, FHWA and the NDEVC staff are helping inspectors ensure the safety of the Nation's bridge infrastructure.

Glenn A. Washer, Ph.D., P.E., is the director of the NDEVC. Dr. Washer received his Ph.D. in materials science and engineering from the Johns Hopkins University in 2001. He received a master's in structural engineering from the University of Maryland in 1996 and his bachelor's in civil engineering from Worcester Polytechnic Institute in 1990. He has been with FHWA for more than 13 years, during which time he has been involved with the development and testing of many NDE technologies for highway bridges and has published more than 40 related conference and journal papers. In 2001, he received the Arthur S. Flemming Award in Applied Science from The George Washington University for his role in developing the NDEVC. Dr. Washer is a registered professional engineer in Virginia.

The following staff from the NDEVC contributed to this article:

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For more information on projects at the NDEVC, visit www.tfhrc.gov/hnr20/nde/home.htm. For information on the use of high-energy x-ray on the Central Artery Tunnel Project, contact Structural Engineer Daniel Wood with the FHWA Division Office in Massachusetts at 617-494-2462 or daniel.c.wood@fhwa.dot.gov.

Along the Road

Along the Road is the place to look for information about current and upcoming activities, developments, trends, and items of general interest to the highway community. This information comes from U.S. Department of Transportation (USDOT) sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.

Personnel

Secretary Mineta Receives 2003 Great Outdoors Award

Recently, USDOT Transportation Secretary Norman Y. Mineta received the recreation community's highest recognition—the Sheldon Coleman Great Outdoors Award.

The American Recreation Coalition honored Secretary Mineta for his contribution to the country's transportation policies for decades. During his career in Congress, Mineta championed increases in investment for transportation infrastructure and was a key author of the landmark Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) that shifted decisions on highway and mass transit planning to State and local governments. ISTEA led to major upsurges in mass transit ridership and more environmentally friendly transportation projects, such as bicycle paths.

The award presentation was one of the events celebrating Great Outdoors Week 2003, which highlighted the partnerships that enable outdoor recreation to contribute to the Nation's health and quality of life. The award honors the efforts of individuals who are helping protect parks, forests, refuges, and other lands.

Policy and Legislation

Ruling Improves Access for Disadvantaged Businesses

In June 2003, USDOT issued a final rule making several improvements to its disadvantaged business enterprise program. The new provisions reduce administrative burdens and clarify program requirements for small businesses, prime contractors, and State and local governments working with the program and competing for USDOT-assisted contracts and grants.

To streamline the process, USDOT created a uniform application form for small businesses to apply for eligibility and implemented a memorandum of understanding between USDOT and the Small Business Administration (SBA) to facilitate certification under the program for SBA-certified small disadvantaged businesses.

To assist prime contractors, USDOT now requires State and local governments to take steps to reduce burdens associated with funds retained at the conclusion of a contract. To address the concern for privacy, the Department will increase privacy protections for confidential business information provided by companies qualifying under this program.

The disadvantaged business enterprise program is administered by State and local recipients of financial assistance from the Federal Highway Administration (FHWA), Federal Transit Administration, and the Federal Aviation Administration. The program seeks to ensure a nondiscriminatory, level playing field for small businesses owned and controlled by socially and economically disadvantaged individuals.

For further information about the rule and new provisions, visit http://dms.dot.gov and do a search using Docket Number OST-2000-7639.

Management and Administration

Mineta Announces $693 Million in Highway Discretionary Funds

In summer 2003, USDOT Secretary Norman Y. Mineta announced $693 million in FHWA discretionary funds for infrastructure projects in all 50 States and the District of Columbia.

The agency awarded States approximately 500 grants in seven categories: borders and corridors, interstate maintenance, bridge replacement and rehabilitation, public lands highways, ferry boats and terminals, intelligent transportation systems, and pilots for transportation, community, and system preservation.

Totals for the States and the District of Columbia are on the Internet at www.fhwa.dot.gov /discretionary/fy03congdes.htm.

FHWA Honors Eight States for Scenic Byways

FHWA and two of its partners at the National Scenic Byways Conference in Albuquerque, NM, recognized projects in eight States with national awards for contributions to enhancing, preserving, and promoting America's byways.

The national competition, "The Road Beckons: Best Practices for Byways," received 37 projects from 21 States. FHWA selected award-winning projects in Florida, Louisiana, Missouri, New Hampshire, New Mexico, North Dakota, Oregon, and Washington. The winning projects included an interim development ordinance to protect environmentally sensitive lands along the A1A corridor in Florida and the restoration of a mountainside to preserve a scenic view along the Sound Greenway in Washington State.

The Department established the National Scenic Byways Program under ISTEA and reauthorized the program in 1998 under the Transportation Equity Act for the 21st Century (TEA-21). To date, the program has provided $202 million to 1,488 projects throughout the country.

To obtain a copy of "The Road Beckons: Best Practices for Byways," or for more information about next year's award cycle, contact Courtney Lyell at 202-366-1929 or courtney.lyell@fhwa.dot.gov.

Mineta Announces Loan for Toll Road In California

Earlier this year, USDOT Secretary Norman Y. Mineta announced that the Federal government executed a $140 million loan for a project on State Route 125 in San

Diego, CA, that involves the design and construction of the South Toll Road.

An international fund is investing more than $150 million to develop and operate the toll road. The loan was made by USDOT under an innovative financing program established by the Transportation Infrastructure Finance and Innovation Act of 1998. The loan proceeds will help finance the design and construction of a 14.8-kilometer (9.2-mile), four-lane toll road that connects State Route 905, near the Otay Mesa port of entry from Mexico, to the region's freeway system about 2.4 kilometers (1.5 miles) south of State Route 54 in Spring Valley.

The SR-125 South Toll Road is a key link in the regional transportation system that is needed to accommodate economic growth in the southern part of San Diego County. The project will facilitate traffic and trade across the U.S.-Mexico border at the Otay Mesa crossing. The estimated cost for the toll road (including preliminary engineering, development costs, construction, and financing) is $642 million.

USDOT Pledges Funding for East Coast Greenway

Assistant Secretary for Transportation Policy Emil Frankel joined Congressional leaders, representatives of the East Coast Greenway Alliance, and health and environmental groups on the National Mall in Washington, DC, to celebrate National Trails Day. The event also announced the creation of the East Coast Greenway, a new trail that will link East Coast cities from Maine to Florida.

The greenway, when completed, will be a 4,184-kilometer (2,600-mile) path that will be closed to motor vehicles. Frankel gave trail markers signed by U.S. Transportation Secretary Norman Y. Mineta to representatives from the East Coast Greenway Alliance to post along the route. The greenway will contribute to a cleaner environment and healthier lifestyles.

Funding under ISTEA and TEA-21 is helping underwrite the trail. Using Federal highway and some transit funding, States and metropolitan areas provided about $400 million for sections of the route.

For more information, visit www.greenway.org.

Public Information and Information Exchange

FHWA Recognizes Six States for Roadside Programs

The editors of *Greener Roadsides*, a quarterly FHWA newsletter for managers of roadside vegetation, recognized six States in the 9th annual Photo Opportunity competition. The competition honors States that submit outstanding photos demonstrating their accomplishments in improving and protecting the roadside environment.

Arizona, Maryland, Minnesota, Missouri, Oregon, and West Virginia submitted first-place photos in 2003. Each first-place winner received a crystal award from the FHWA division office in its State. *Greener Roadsides* publishes the winning photos, and FHWA may feature the winners in brochures, videos, presentations, and future Earth Day calendars.

Seventeen States submitted 133 photos in seven categories. Missouri, a consistent winner each year, won awards in two categories. The jury that selected the winning photos consisted of staff from FHWA headquarters representing various disciplines, including graphic design, landscape architecture, law, and public affairs. The judges described the winning entries as "wonderful" and offered "accolades in general" to all the participating States.

To view the winning entries or learn more about the photo competition, contact Bonnie Harper-Lore, editor of Greener Roadsides, *at 651-291-6104 or bonnie.harper-lore@fhwa.dot.gov.*

Missouri DOT

These intensely blue downy gentians are uncommon flowers on Missouri roadsides.

FHWA Promotes Simpler, Smarter Ways To Protect Wildlife along Roads

Earlier this year, FHWA announced the start of a first-of-its-kind Web site that highlights examples of simple, low-cost techniques for protecting wildlife and fish near transportation facilities.

The Web site, "Keeping It Simple: Easy Ways to Help Wildlife Along Roads," includes more than 100 success stories from all 50 States. The activities featured on the site range from installing nesting boxes to modifying maintenance schedules. Users can search the site by State or by one of four categories: Along Roads, On or Near Bridges, On or Along Waterways, and On Wetlands and Uplands.

Crashes between motor vehicles and animals account for a large percentage of the total crashes in many areas, and the number continues to rise. More than 200 motorists die each year in animal-vehicle collisions, and thousands more are injured, according to FHWA statistics. Many of the best practices featured on the site not only help protect wildlife, but they also improve highway safety for motorists nationwide.

Visit the "Keeping It Simple" Web site at www.fhwa.dot.gov/environment/wildlifeprotection.

USDOT Releases Major Survey on Biking and Walking

Nearly 80 percent of adults in the United States take at least one walk of 5 minutes or longer during the summer months. But fewer than 30 percent ride a bike, according to a major new survey released by USDOT.

The survey, conducted jointly by the Bureau of Transportation Statistics and the National Highway Traffic Safety Administration, revealed that only half of all adults are satisfied with the design of their communities for safe bicycling. But three out of four adults are satisfied with their communities in terms of pedestrian safety.

Findings from the survey show a steep decline in bicycling and a more gradual decline in walking as people age. Some of the reasons cited for not walking or riding a bike include lack of access to a bicycle, disability or other health problems, unfavorable weather, and lack of opportunity.

The National Survey of Pedestrian and Bicyclist Attitudes and Behaviors involved phone interviews with more than 9,600 adults age 16 and older throughout the United States. USDOT conducted the survey during a 10-week period in the summer of 2002.

For more details about the survey results, visit www.bicyclinginfo.org or www.walkinginfo.org.

New Web Site Helps Agencies Manage Transportation Security

This year, FHWA announced a new "FHWA Operations Security" Web site to provide State and local agencies simple access to information on improving security operations for surface transportation. The Web site was created to help State and local agencies effectively plan, operate, and apply security technology.

A section of the Web site offers specific information on how to plan for emergencies, align action plans with the Nation's Homeland Security Advisory System, and improve military mobilization, because roads are critical for response and recovery strategies.

The Web site offers links to information on transportation security from all of the Department's administrations, other Federal agencies, and the associations participating in the National Associations Working Group for ITS. The site also links to articles, research, and other information related to transportation security.

To access the new Web site, visit www.ops.fhwa.dot.gov/OpsSecurity. For more information on traffic operations, visit www.ops.fhwa.dot.gov.

Best Practices Report Released on Rural Transit

FHWA has released *Rural Transit ITS Best Practices (FHWA-OP-03-77)*. The report identifies operational best practices for applying ITS technologies to rural transit. The recommendations are based on case studies performed onsite at five rural transit agencies.

To develop the case studies, USDOT staff visited the Capital Area Rural Transportation System in Austin, TX; St. Johns, Marion, and Putnam counties, FL; the Public Transportation Programs Bureau, statewide in New Mexico; Ottumwa Transit Authority in Ottumwa, IA; and River Valley Transit in Williamsport, PA.

The report addresses the use of ITS technologies at rural transit agencies, institutional and organizational issues, ITS applications and technology, funding and other financial considerations, benefits of rural ITS projects, and the deployment process. USDOT presents the recommendations as guidance for other agencies that are considering implementing rural ITS solutions.

FHWA selected the Capital Area Rural Transportation System in Austin as a case study because it uses a sophisticated 900-megahertz, two-way radio system combined with automated demand-responsive transportation-scheduling software. David Marsh, executive director of the Capital Area Rural Transportation System, cites a slow, measured approach to implementing new technology as the key to success. "We now have moved to mobile data computers with automatic vehicle-location and magnetic card readers," he says, "and the phased approach again proved its value as we were able to work through the complexities of executing this next level of ITS deployments from a foundation on our past experience. If we had attempted all of it at once, we would surely have floundered and failed."

The Florida Commission for the Transportation Disadvantaged assisted a number of rural areas in deploying low-cost ITS applications, such as a demand-response software suite that helps manage call intake and payroll and schedule vehicles, staff, and trips.

New Mexico's Public Transportation Programs Bureau and the Alliance for Transportation Research Institute developed a statewide, Web-based software application that authorizes and schedules trips, tracks riders, bills trips, and generates reports—saving time and money.

The Ottumwa Transit Authority, which provides bus service in Ottumwa, IA, and the surrounding 10-county area, installed a four-tower, 150-megahertz radio system to provide communications for its automatic vehicle-location system and mobile-data terminals.

And River Valley Transit installed automatic vehicle-location and mobile-data terminals on its fixed-route buses to provide real-time, in-terminal customer information, enabling the agency to inform customers visually and audibly about where buses will arrive and depart from.

For more information about these projects, access the Rural Transit ITS Best Practices Report *at www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13784.html.*

Internet Watch

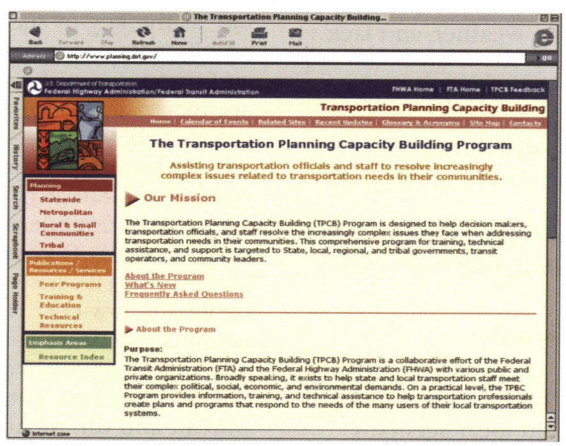
by Keri A. Funderburg

Planning Made Simple

The *Merriam-Webster Online Dictionary*© defines the word "collaborate" as "to cooperate with an agency or instrumentality with which one is not immediately connected." In transportation planning, collaboration normally is part of every successful project. Planning requires the input, cooperation, and resources of many people and organizations, including officials from State and local governments, law enforcement officials, transit and environmental agencies, and the public.

By accessing the new "Transportation Planning Capacity Building" Web site (www.planning.dot.gov), transportation professionals, decisionmakers, and the public can find ways to collaborate and learn about the complex issues involved in meeting a community's transportation needs. Developed by the Federal Highway Administration (FHWA), Federal Transit Administration, American Association of State Highway and Transportation Officials, American Public Transportation Association, and the Association of Metropolitan Planning Organizations, the comprehensive site features basic and technical planning resources and information on peer programs and training.

"The new Web site serves as a centralized clearinghouse for information on transportation planning," says Robert Ritter, the leader of FHWA's Planning Capacity Building Team. "We developed it to be a first stop for transportation professionals, decisionmakers, and the public to find answers to their planning questions."



The Transportation Planning Capacity Building Web site.

Information at All Levels

The capacity-building Web site contains transportation planning sections at the statewide, metropolitan, rural, and tribal levels. Each section has information on planning-related legislation, links to training courses on the planning process, and technical resources and case studies on a variety of topics from a number of geographical areas.

Users can find links to an evaluation report on statewide transportation plans, a guidebook on travel forecasting, and summaries of best practices. For users interested in metropolitan transportation planning, the site includes links to the Federal requirements for creating new metropolitan planning organizations (MPOs) and case studies on the development of 10 MPOs.

The section on planning for rural and small communities includes information on data needs in rural areas and a link to the Rural Transport Toolbox—a project by the U.S. Department of Transportation (USDOT) and the U.S. Department of Agriculture to improve agricultural, passenger, and freight mobility. When consulting with tribal governments on planning issues, users can access links to tribal-specific legislation, samples of programmatic agreements between government agencies and Native American tribes, and case studies on environmental justice.

Beyond the Basics

The site also features a calendar of events listing upcoming meetings and conferences and introduces the Transportation Planning Capacity Building Peer Program, which offers opportunities for professionals to share solution-based experiences with other members of the transportation planning community.

The Peer-to-Peer Exchange enables transportation professionals to contact FHWA or the Federal Transit Administration to request technical assistance on institutional or policy issues. During 1-day roundtable discussions, transportation and planning experts can share their experiences with peers. Workshops provide an opportunity for professionals to learn about new techniques and tools for transportation planning in a classroom format.

For those seeking technical resources, the Web site features an index of publications on various topics, such as funding and smart growth, and indicates the availability of training information, publications, case studies, and other Internet links on each issue. In the "Topic Areas" section of the site, users will find links to USDOT sites relating to freight, the human and natural environments, land use, MPOs, public involvement, safety, and transportation modeling.

The capacity-building site also has a glossary of transportation terms and acronyms commonly used during the planning process. The glossary provides definitions for words and acronyms ranging from "area sources" and "ADT" to "urbanized areas" and "VPD."

By visiting the Transportation Planning Capacity Building Web site, transportation professionals and others can access the information and tools to collaborate effectively with the many agencies and people critical to improving the safety and mobility of the Nation's transportation system.

Keri A. Funderburg is a contributing editor for PUBLIC ROADS.

Communication Product Updates

Compiled by Zac Ellis of FHWA's Office of Research and Technology Services

Below are brief descriptions of products recently published online by the Federal Highway Administration's (FHWA) Office of Research, Development, and Technology. Some of the publications also may be available from the National Technical Information Service (NTIS). In some cases, limited copies are available from the Research and Technology (R&T) Product Distribution Center.

When ordering from NTIS, include the NTIS publication number (PB number) and the publication title. You also may visit the NTIS Web site at www.ntis.gov to order publications online. Call NTIS for current prices. For customers outside the United States, Canada, and Mexico, the cost is usually double the listed price. Address requests to:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703–605–6000
Toll-free number: 800–553–NTIS (6847)

Address requests for items available from the R&T Product Distribution Center to:

R&T Product Distribution Center, HRTS-03
Federal Highway Administration
9701 Philadelphia Court, Unit Q
Lanham, MD 20706
Telephone: 301–577–0818
Fax: 301–577–1421

For more information on research and technology publications from FHWA, visit the Turner-Fairbank Highway Research Center's (TFHRC) Web site at www.tfhrc.gov, FHWA's Web site at www.fhwa.dot.gov, the National Transportation Library's Web site at http://ntl.bts.gov, or the OneDOT information network at http://dotlibrary.dot.gov.

Guidelines for the Use of Lithium to Mitigate or Prevent ASR
Publication No. FHWA-RD-03-047

Alkali-silica reaction (ASR) is a significant durability problem that results in premature deterioration of various types of concrete structures in the United States and throughout the world. Although several viable methods exist to prevent ASR-induced damage in new concrete structures, few methods mitigate further damage in structures already affected by expansion and cracking due to ASR. For more than 50 years, researchers have recognized that lithium compounds effectively prevent expansion caused by ASR, and in recent years there has been renewed interest in using lithium compounds either as an admixture in new concrete or as a treatment for existing structures. This report provides practitioners with the necessary information and guidance to test, specify, and use lithium compounds in new concrete construction and in applications to repair and extend service life.

First, the report provides a basic overview of ASR, including information on mechanisms, symptoms of damage in field structures, mitigation approaches, test methods, and specifications. A comprehensive summary of lithium compounds follows, including information on their production, availability, and use in concrete studies in the laboratory and in field applications (including a range of case studies). Next, the authors present guidelines for using lithium compounds as an admixture in new concrete and for testing existing structures suffering from ASR-induced damage, including information on how to assess the efficacy of lithium compounds in laboratory tests. Some basic information also is provided on the economics of using lithium in new concrete and as a treatment for existing structures. Finally, the report provides a summary of conclusions and identifies several technical and practical issues that should be considered for future laboratory studies and field applications.

Optimal Procedures for Quality Assurance Specifications
Publication No. FHWA-RD-02-095

This manual is a comprehensive guide that a highway agency can use when developing or modifying specifications for acceptance plans and quality assurance. It provides necessary instruction and illustrative examples to lead the agency through the entire process of developing acceptance plans, including:

- Setting up the initial data collection and experimentation to determine typical parameters for current construction
- Establishing the desired level of quality to be specified
- Designing the actual acceptance plan, including selecting quality characteristics, statistical quality measures, risks for buyers and sellers, lot sizes, numbers of samples (samples, sizes), specification and acceptance limits, and payment-adjustment provisions
- Monitoring how the acceptance plan is performing
- Making necessary adjustments

Long-Term Effectiveness of Cathodic Protection Systems on Highway Structures
Publication No. FHWA-RD-01-096

Based on extensive study, FHWA researchers conclude that cathodic protection—the technology used to mitigate corrosion of metals embedded in concrete—is the only rehabilitation technique that has proven to stop corrosion in salt-contaminated bridge decks regardless of the chloride content of the concrete. This technology is based on applying an external source of current to counteract the internal corrosion current produced in reinforced concrete components. During cathodic protection, current flows from an auxiliary anode material through the electrolyte (concrete) to the surface of the reinforcing steel.

Assorted materials in different configurations are used as auxiliary anodes for cathodic protection, resulting in various types of systems. The selection of the anode material and its configuration is paramount to the success of the system. The primary objective of this 5-year study was to determine the effectiveness of various materials and configurations when used as auxiliary anodes on highway structures during a long-term evaluation.

In this study, researchers looked at 20 highway structures (19 bridges and 1 tunnel) protected by one or more cathodic protection systems. The structures, located in 11 States and 1 Canadian Province, were protected by a total of 19 impressed-current and 5 galvanic systems. FHWA selected most of the structures based on previous studies performed under the Strategic Highway Research Program; the current study was funded under the continuation of that program.

The findings of the study summarize the protection provided by the systems evaluated and estimate the expected service life for the anode materials in similar environments. On some structures, the systems were operated at insufficient output current, resulting in poor performance. If these systems had been operated at higher output currents, their performances would have been rated higher.

NATIONAL HIGHWAY INSTITUTE

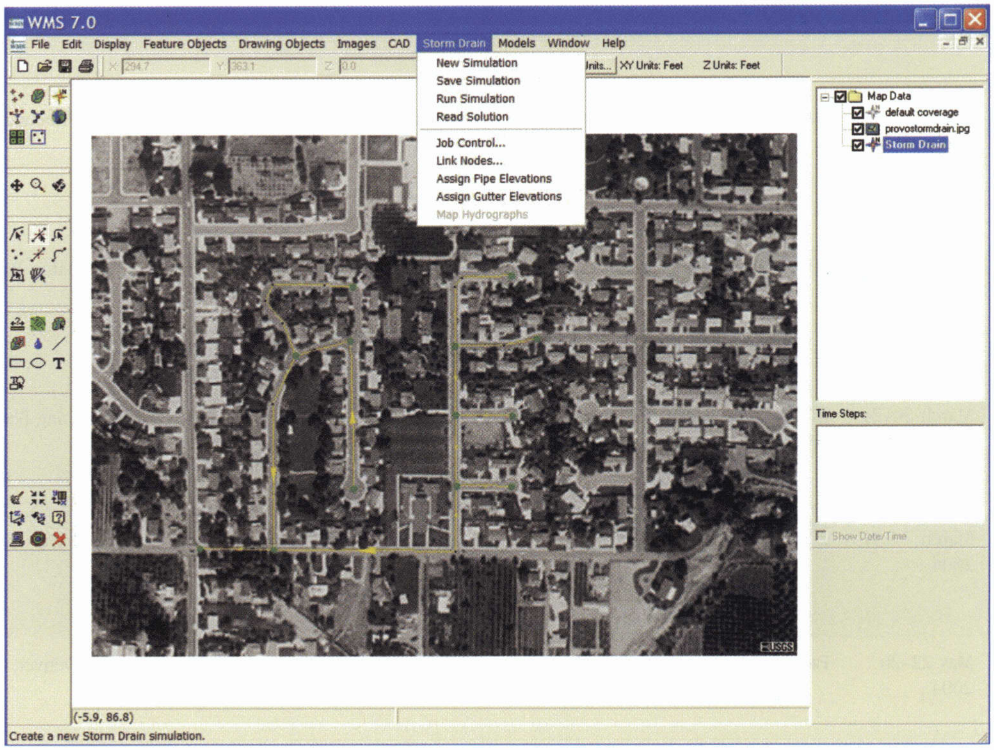
Training Update

How Does Water Cross The Road?

When designing roads, engineers must consider the project's proximity to streams, lakes, wetlands, oceans, and other permanent and seasonal water bodies. Understanding how water gets from one side of the road to the other is at the heart of the curriculum for a new course offered by the National Highway Institute (NHI) at the Federal Highway Administration (FHWA).

Introduction to Highway Hydraulics Software (#135081A) introduces engineers and roadway designers to state-of-the-practice software and technologies available for designing appropriately sized, cost-effective bridges and culverts.

"The bigger they are, the more they cost," says Larry Arneson, senior hydraulics engineer at FHWA's Resource Center in Lakewood, CO. "Our goal for the course is to offer an overview of the different computational tools available to hydrologic and hydraulic engineers to help them build the safest and most cost-effective structures."



This screen capture from the Watershed Modeling System used during the course shows a conceptual layout of a storm drain system in an urban setting, including inlets, junctions (access holes), and connectors (pipes).

Participants will learn from hands-on experience in selecting and applying software tools in the design of drainage facilities and hydraulic structures. The course focuses on estimating peak flows and hydrographs, performing hydraulic analyses of culverts and storm drain analyses, designing detention ponds, and assessing channel hydraulics. In particular, attendees will be able to input data into specific hydraulic software tools, such as the Watershed Modeling System, and then interpret and apply the results.

The course focuses on practical analysis and design skills through a variety of exercises, including the use of a typical watershed as a case study. Participants apply theoretical and practical knowledge to the case study and learn from examples that easily relate to their day-to-day work.

The course is intended for highway engineers and designers who are responsible for the hydrologic and hydraulic aspects of designing storm drains, culverts, detention basins, and channels. Participants should have an overall knowledge of hydrology and hydraulics.

Upon completing the course, participants will be able to do the following:

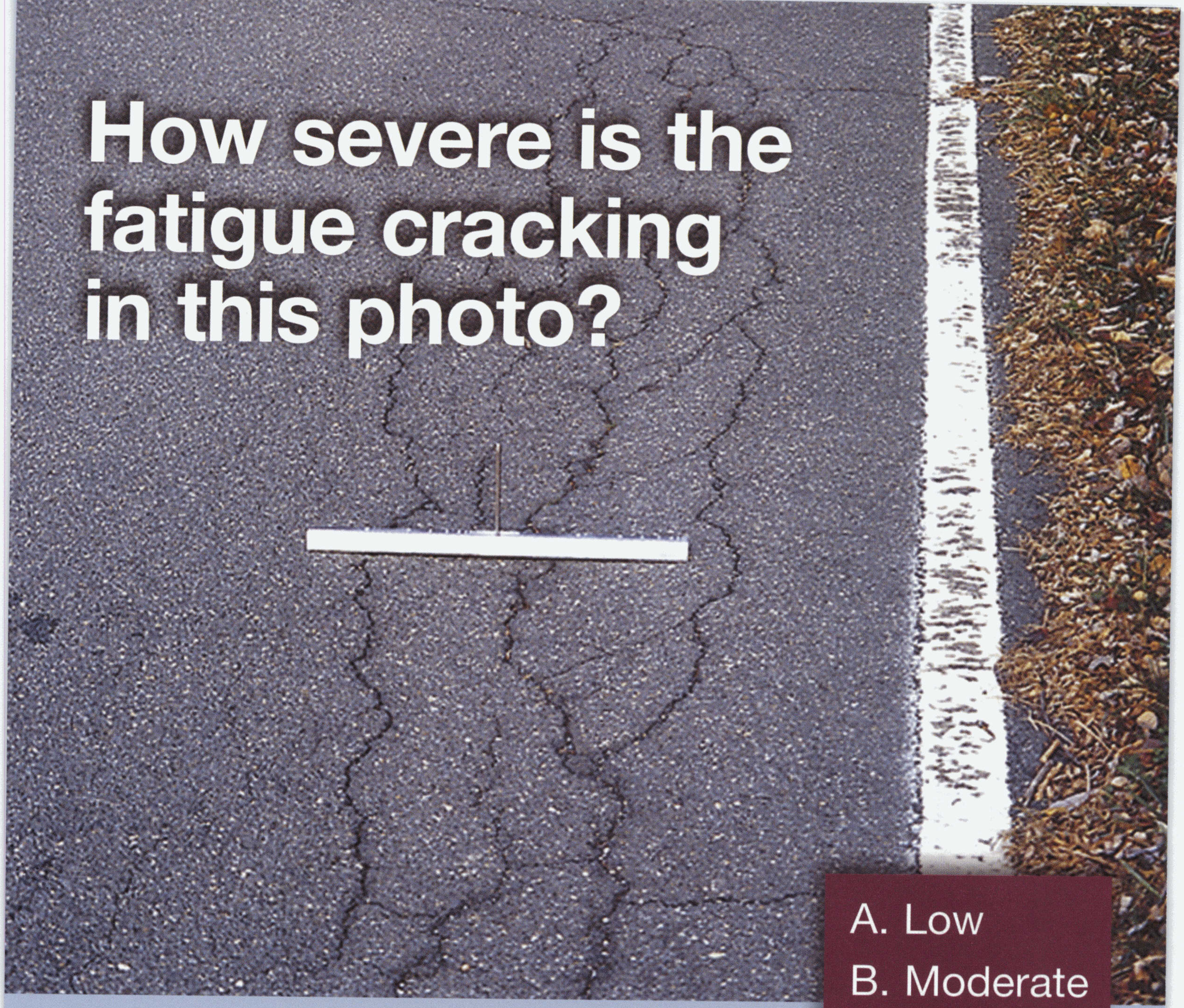
- Choose appropriate software for various design situations
- Identify the data needs for software applications
- Input data into the software tools and interpret the results
- Apply appropriate hydraulic tools to designing drainage facilities and hydraulic structures

The course will be available by late 2003 or early 2004. Parties interested in sponsoring the 3-day course must have access to a computer classroom. The class size is limited to 24 participants.

For technical information regarding the Introduction to Highway Hydraulics Software course, contact Joe Krolak at 202-366-4611 or joseph.krolak@fhwa.dot.gov. To learn more about transportation-related training courses available from NHI, consult the course catalog at www.nhi.fhwa.dot.gov or contact NHI at 4600 N. Fairfax Drive, Suite 800, Arlington, VA 22203; 703-235-0500 (phone); or 703-235-0593 (fax). For scheduling, contact Danielle Mathis-Lee at 703-235-0528 or danielle.mathis-lee@fhwa.dot.gov.

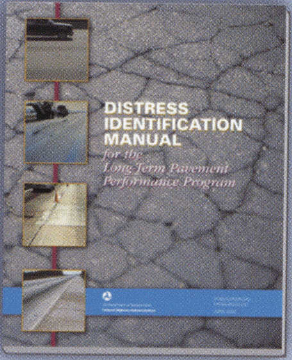
Conferences/Special Events Calendar

Date	Conference	Sponsor	Location	Contact
Jan 11-15 2004	Transportation Research Board 83rd Annual Meeting	Transportation Research Board (TRB)	Washington, DC	Linda Karson 202-334-2003 lkarson@nas.edu www.trb.org/trb/meeting
Jan 18-21 2004	NAPA's 9th Annual Convention	National Asphalt Pavement Association (NAPA)	Phoenix, AZ	Meetings 888-468-6499 (toll free) 301-731-4748 meetings@hotmix.org www.hotmix.org
March 8-10 2004	AAPT Annual Meeting	Association of Asphalt Paving Technologists (AAPT)	Baton Rouge, LA	Eileen Soler 651-293-9188 aapt@qwest.net www.asphalttechnology.org
March 20-24 2004	IBTTA Organization Management Workshop	International Bridge, Tunnel, and Turnpike Association (IBTTA)	Long Beach, CA	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
March 28-31 2004	2004 ITE Technical Conference	Institute of Transportation Engineers (ITE)	Irvine, CA	Lisa Zahurones 202-289-0222, ext. 136 lzahurones@ite.org www.ite.org
May 22-26 2004	Facilities Management Workshop	IBTTA	Denver, CO	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
June 1 2004	6th International Symposium on Snow Removal and Ice Control Technology	TRB	Spokane, WA	Frank Lisle 202-334-2950 flisle@nas.edu http://gulliver.trb.org/calendar/event.asp?id=53
June 13-15 2004	Technology Workshop	IBTTA	Miami Beach, FL	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
June 27-30 2004	North American Travel Monitoring Exposition and Conference (NATMEC) 2004	Federal Highway Administration (FHWA) and TRB	San Diego, CA	Thomas Palmerlee 202-334-2907 tpalmerlee@nas.edu http://gulliver.trb.org/calendar/event.asp?id=16
July 21-24 2004	Highway Capacity and Quality of Service Committee (A3A10) Midyear Meeting and Conference	TRB	State College, PA	Richard Cunrad 202-334-2965 rcunard@nas.edu http://gulliver.trb.org/calendar/event.asp?id=55
July 27-31 2004	Geo-Trans 2004	American Society of Civil Engineers (ASCE)	Los Angeles, CA	Leonore Jordan 703-295-6110 ljordan@asce.org www.asce.org/conferences/geotrans04
August 1-4 2004	2004 ITE Annual Meeting	ITE	Lake Buena Vista, FL	Lisa Zahurones 202-289-0222, ext. 136 lzahurones@ite.org www.ite.org



A. Low
B. Moderate
C. High

*Answer below



Even if you know the answer, the newly updated

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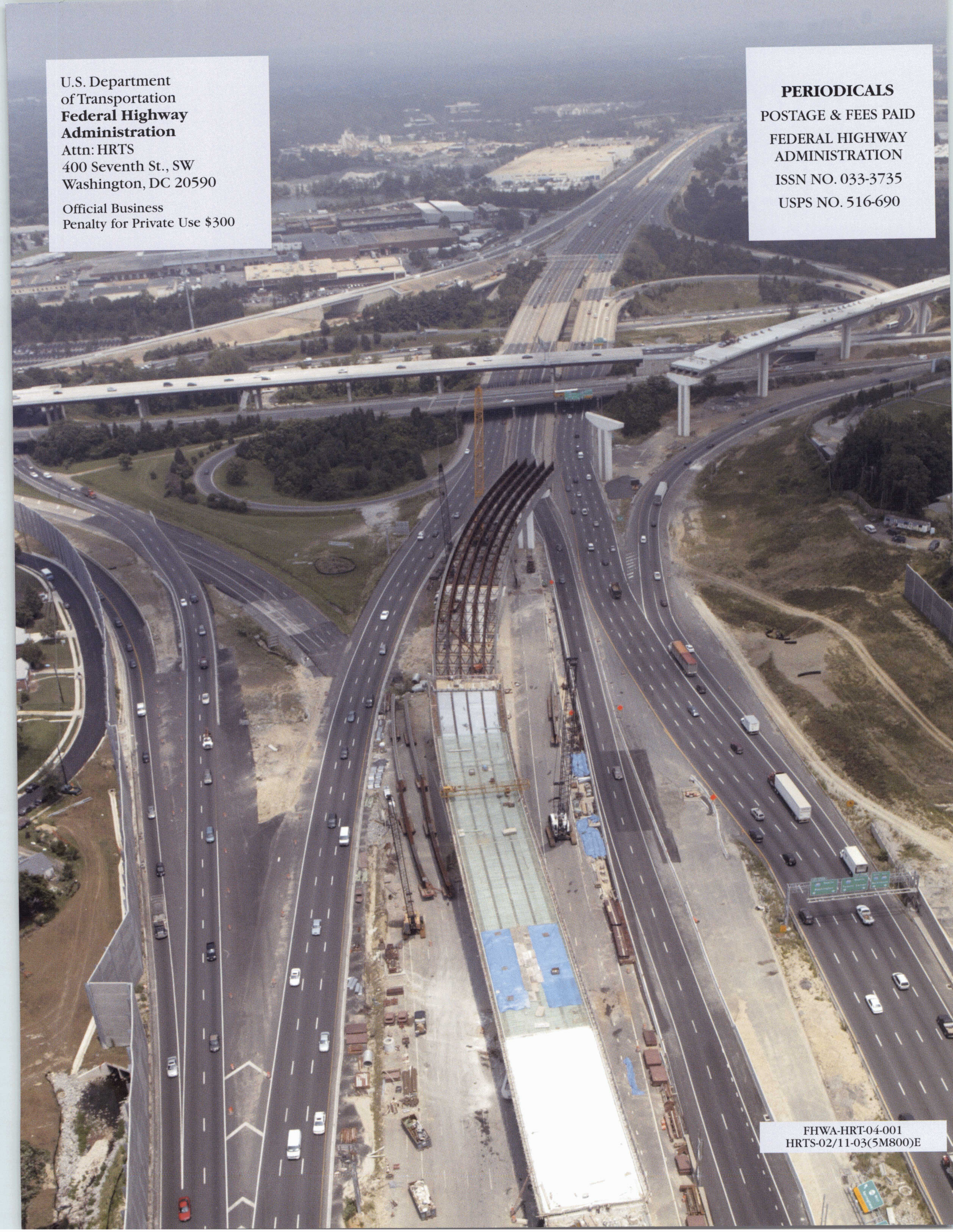
*Answer: B. Moderate



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